# ENCYCLOPEDIA OF EXPLOSIVES AND RELATED ITEMS

## PATR 2700

## VOLUME 2


BY

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## PREFACE

This volume is a continuation of efforts to cover comprehensively the subject matter, in the same manner & format, as in Vol I. The user is urged to read both the PREFACE and INTRODUCTION in Vol I to understand the authors' way of treating the subject matter

In compiling this Encyclopedia, the authors have consulted freely with, and had the cooperation of many individuals. Throughout this work, information received from individuals is acknowledged in the text. A listing of others who have been consulted or who have helped in other ways would be impractical. Mr Henry A. Aaronson who retired from Picatinny Arsenal in 1957, after 35 years of service in the field of propellants & explosives, contributed significantly by collecting some references, reviewing some portions of the preliminary manuscript, and by helpful discussions in other areas. Mr George D. Clift, formerly of Picatinny & of the Army Chemical Center, Edgewood, Md reviewed the pencil copy, made some suggestions for revision, and typed the complete copy of this manuscript. It is with deep sorrow & sad regret that we record here the death of George D. Clift on 13 August 1962, after 45 years of experience in the field of propellants & explosives

Mr L. H. Eriksen, Chief of Explosives & Propellants Laboratory, Picatinny Arsenal reviewed the entire manuscript, and thru his interest, encouragement & guidance this publication is possible. Special acknowledgement is due also to other officials (both military and civilian) of Picatinny Arsenal for approving this work and for obtaining its financial support. Picatinny Arsenal reference works were made available thru the cooperation of all Technical Information (Library) personnel, Mr H. Voos, Supervisory Librarian and Mr M. A. Costello, Section Chief

Although considerable effort has been made to present this information as accurately as possible, mistakes & errors in transcription do occur. The authors welcome the reader of this Encyclopedia to feel free to point out mistakes & errors, so that corrections can be listed in the next volume. The interpretations of data & opinions expressed are the responsibility of the authors and are not necessarily those of Picatinny Arsenal or of the Department of the Army. This report has been prepared for information purposes only and the Department of the Army or Picatinny Arsenal shall not be responsible for any events or decisions arising from the use of this information

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## Errata in Vol 1

| Page | |
|---|---|
| Abbr 9-L | Bzl = Benzyl, $C_6H_5 \cdot CH_2-$ instead of $C_6H_5 \cdot CH-$ |
| Abbr 41-R | Add: propln = propulsion<br>propn(s) = proportion(s) instead of propulsion<br>Delete ps = parts per second |
| Abbr 46-L | SC = Solventless Cordite instead of solventless, carbamite |
| Abbr 52-R | TNBAc instead of TNBA for Trinitrobenzoic Acid |
| Abbr 52-R | TNBzN = Trinitrobenzoyl Nitrate instead of Trinitrobenzyl Nitrate |
| Abbr 65-R | Delete WAAC = Woolwich Arsenal |
| Abbr 72, 5th line from the bottom | RevScInst instead of RevChimInd |
| Abbr 73, 10th line from the bottom | Thorpe(1940) instead of Thorpe(1949) |
| Abbr 74, 2nd line | Ullmann, vol 4(1929) instead of vol 4(1926) |
| Abbr 75, 12th line from the bottom | Esplosivi instead of Explosivi |
| A16-L | Delete DNN = Dinitronaphthol |
| A83-R, line 9 | Formula should read: $C_3H_5O_3(CH_3CO)(C_{11}H_{23}CO)_2$ instead of $C_3H_5O_3(CH_3CO)(C_{11}H_2O)_2$ |
| A98-L, two bottom lines | Replace with **Action of Gas Explosions on Solid Explosives** |
| A178-L, lines 5 & 6 | Formula of Tricrotonylidenetriperoxide-tetramine should read: $H_2N \cdot R \cdot NH \cdot CH \cdot R \cdot NH \cdot R \cdot NH_2$, where R is $MeCH{:}CH \cdot O_2 \cdot CH=$ |
| A191-R | Insert at the bottom of the page the following: *Note:* M.H.Werther, Rec **52**, 657-77(1933) & CA **27**, 5069-70(1933) describes o- and p-biphenyls as 2- and 4-*xenylamines*. He also describes prepn and props of **3,5,4'-trinitro-2-xenylamine** (mp 227°); **3,5,4'-trinitro-4-xenylamine** (mp 280°) and **3,5,2',4'-tetranitro-4-xenylamine** (mp 253°). Their expl props were not investigated |
| A215-R, lines 15,16 & 17 | Delete the sentence beginning with: **Aminoguanylnitrosaminoguanyl-tetrazene,** designated..... |
| A224-L, lines 8 & 9 | Delete: *Benzodiazole or Benzopyrazoles* from the title |
| A224-L, line 10 | Make: [59] instead of 59 and [308] instead of 308 |
| A224-L, line 12 | *Indazolonimides* instead of *Indazolonimide* |
| A225-L, line 10 | Name should read: **1'-Amino-mesitylene; 1'-Amino-1,3,5-trimethyl-benzene; 3,5-Dimethylbenzylamine or Mesitylamine,** |
| A253-L, lines 5,6,7 & 8 from the bottom | Replace with: Nitroaminopropanol Nitrate, $C_3H_7N_3O_5$ and Dinitroaminopropanol, $C_3H_7N_3O_4$- not found in Beil or CA thru 1956 |

| | |
|---|---|
| A483-L | The last 4 lines should read: is called **APC** (armor-piercing capped) and the cap is known as *ballistic cap*. This cap is covered with a conical cup called *windshield* or *false ogive*, the purpose of which is..... |
| A523 | Barium Diazide, mw 221.41, N 37.96%; instead of mw 243.43, N 51.79%; |
| A603-R, line 14 | Replace $C_2H_5$ ONO with $C_2H_5$ $ONO_2$ |
| A630-L, lines 5, 6 & 7 from the bottom | Delete the sentence beginning with: **Azidobenzenediammoniumhydroxide.** See..... and replace it with: **Azidobenzenediazonium Hydroxide.** See under Benzenediazonium Hydroxide and Derivatives |
| A643-L, line 21 | Delete: Azidotrinitromethane. See under Methane |
| A676-L, Ref 21 | Delete: dash (–) between Pepin Lehalleur |
| A676-L, Ref 31 | A. Pérez Ara instead of A. Perez Ara |
| A676-R, Ref 38 | Delete: comma(,) after Buenos |
| A678-R, 1st line | Change to read: Ballistic Cap and Windshield A483-L |
| A678-R, lines 18 & 19 | Delete: Benzodiazole,Benzopyrazole or Aminoindazole A224-L |
| A692-R, line 3 | Change to read: Ballistic Cap and Windshield A483-L |

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## SUPPLEMENT TO ABBREVIATIONS, CODE NAMES AND SYMBOLS GIVEN IN VOL 1, pp Abbr 1 to 65

| | |
|---|---|
| acct | account |
| AMC | Army Materiel Command, formerly OCO, Washington 25, D.C. |
| BDSD | Base-detonating self-destroying (fuze) |
| Bzl | Benzyl, $C_6H_5.CH_2-$ instead of $C_6H_5.CH-$, which was given in Vol 1, p Abbr 9 |
| capy | capacity |
| CC | Closed Cup (for detg flash point) |
| Centr 1 | N,N'-Diethylcarbanilide or EtCentr |
| Centr 2 | N,N'-Dimethylcarbanilide or MeCentr |
| Centr 3 | N-Ethyl-N'-methyl-carbanilide |
| Centr 4 | N-Methyl-N'-tolyl-carbanilide |
| CPCEM | Compagnie de produits chimiques et électrométallurgiques, Alais, Froges & Camargue |
| descr(d) | describe(d) |
| destruc | destructive |
| destrucn | destruction |
| DEtPh | Diethylphthalate |
| DPhU | Diphenylurea |
| EAM | Electric accounting machine |
| Eg or eg | Example or for example |
| elevtd | elevated |
| EtCentr | Ethyl Centralite |
| extrmly | extremely |
| flamy | flammability |
| fractn | fraction |
| fractnl | fractional |
| hydrcar(s) | hydrocarbon(s) |
| insens | insensitive |
| insensy | insensitivity |
| LASER | Light Amplification by Simulated Emission of Radiation |
| MASER | Microwave Amplification by Simulated Emission of Radiation |
| MeCentr | Methyl Centralite |
| milit | military |
| OC | Open Cup (for detg flash point) |
| OEHO | Ordnance Engineering Handbook Office (Duke Univ, Durham, NC) |
| ORDP | Ordnance Pamphlet |
| PEPA | Projectile empenné à propulsion additionnelle (Fr for Finned Projectile with Additional Propulsion) |
| MA | mixed acid (sulfuric & nitric acids) |
| MUCOM | Munitions Command, formerly OSWAC, Dover, N.J. |
| PERT | Program Evaluation Review Techniques |
| PWP | Plasticized with white phosphorus |
| SACMS | Scientific Advisory Council of Ministry of Supplies (GtBritain) |
| SC | Solventless Cordite, in lieu of Solventless Centralite given in Vol 1, p Abbr 46 |
| TCC | Tag Closed Cup (for detg flash point) |
| TNBAc | Trinitrobenzoic Acid in lieu of TNBA given in Vol 1, p Abbr 52 |
| TNBzN | Trinitrobenzoyl Nitrate in lieu of Trinitrobenzyl Nitrate given in Vol 1, p Abbr 52 |
| TNPhlGl | Trinitrophloroglucinol |
| TOC | Tag Open Cup (for detg flash point) |
| WADC | Wright Air Development Center, changed to WADD |
| WADD | Wright Air Development Division, formerly WADC |

# SUPPLEMENT TO THE LIST OF ABBREVIATIONS FOR BOOKS AND PERIODICALS GIVEN IN VOL 1, pp Abbr 66 to Abbr 76

| | |
|---|---|
| ADL Punch Cards, Vol (1961) | Arthur D. Little Inc, "Punch Card Recording of Data on Explosives," Cambridge, Mass, Vols 1,3 & 4(1961(U) and Vol 2(1961)(C) |
| ADL PureExplCompds (Part & Year) | Arthur D. Little, Inc, "Report on Study of Pure Explosive Compounds," Cambridge, Mass, Part 1(1947); Part 2(1947) Part 3(1950) & Part 4(1952) |
| ADL, SynthesisHE's (Rept & Year)(C) | Arthur D. Little, Inc, "Synthesis and Testing of High Explosives," Cambridge, Mass, 1st Report(1949), 2nd Rept(1951), 3rd Rept(1953) & 4th Rept(1956)(Conf) |
| AFCJ | Armed Forces Chemical Journal, Washington 6, DC |
| Blasters'Hdb(1952) | instead of Blaster's Hdb(1952) of Vol 1, p Abbr 67 |
| Corner,Ballistics(1950) | J.Corner,"Theory of Internal Ballistics of Guns,"Wiley, NY(1950) |
| DictGuidedMissiles(1959) | G.Merrill, Edit, "Dictionary of Guided Missiles and Space Flight,"VanNostrand, NY(1959) |
| Ellern, Pyrotechnics(1961) | H.Ellern, "Modern Pyrotechnics" ChemPublgCo, NY(1961) |
| Encyclopedia 1(1960) | B.T.Fedoroff et al, "Encyclopedia of Explosives and Related Items," PATR 2700(PB No 171603), Dover, NJ(1960) |
| Faber, Pyrotechnics (Vol & Year) | H.B.Faber, "Military Pyrotechnics," USGovtPtgOff, Washington 25, DC, Vols 1,2 & 3(1919) |
| Farrow's MilitaryEncycl (1895) | E.S.Farrow, "Military Encyclopedia,"Military-Naval Pubg Co, NY, Vols 1-3(1895) |
| Feigl(Vol & Year) | F.Feigl, "Spot Tests," Elsevier, Amsterdam, Vol 1 (Inorganic)(1954) and 2 (Organic)(1956) |
| Gardner's ChemSynonyms | W.Gardner & E.I.Cooke, "Chemical Synonyms and Trade Names," VanNostrand, NY(1948) |
| Giua, Trattato 6(1959) | M.Giua et al, "Trattato di Chimica Industriale," UTET, Torino, Vol 6(1959) |
| Glossary of Ord(1959) | W.H.Holler, Edit, "Glossary of Ordnance Terms," OEHO, Duke Univ, Durham, N.Carolina(1959) |
| GreatChemists(1961) | E.Farber, Edit, "Great Chemists," Interscience, NY(1961) |
| Greener(1881) | W.W.Greener, "The Gun and Its Development," Cassell, Petter & Co, London(1881) |
| Jacobson(Vol & Year) | C.Jacobson, "Encyclopedia of Chemical Reactions," Reinhold, NY, Vol 1(1946), 2(1948), 3(1949), 4(1951), 5 (1953), 6(1956), 7(1958) & 8(1959) |
| Macmillan's Encycl (Vol & Year) | "The Macmillan Everyman's Encyclopedia," Macmillan, NY, Vol 1(1959) |
| Marshall,Dict(1920) | A.Marshall, "Dictionary of Explosives," Churchill, London (1920) |

| | |
|---|---|
| Mellor(1961) | "Mellor's Modern Inorganic Chemistry," Revised and edited by G.D.Parkes, Longmans, Green & Co, London(1961) |
| OrdTechTerm(1962) | Anon, "Ordnance Technical Terminology," Special Test ST **9-152**, Aberdeen Proving Ground, Md(1962) [Replaces Glossary of Ord(1959)] |
| RevSciInst | instead of RevChimInd in Vol 1, p Abbr 72 of Encyclopedia |
| RocketEncycl(1959) | J.W.Herrick, E.Burgess & W. Lanford, "Rocket Encyclopedia Illustrated," AeroPublishers, LosAngles, Calif(1959) |
| SACMS,Ballistics(1951) | Scientific Advisory Council of Ministry of Supplies (Great Britain), F.R.H.Hunt, Chairman, "Internal Ballistics," Philosophical Library, NY(1951) |
| Snell & Snell (Vol & Year) | F.D.Snell & C.T.Snell, "Colorimetric Methods of Analysis," Van Nostrand, NY, Vol **I**(1948), **II**(1949), **III**(1953) & **IV** (1954) and Supplementary Vols **IIA**(1959) & **IIIA**(1961) |
| Taylor (1952) | J.Taylor, "Detonation in Condensed Explosives," Clarendon Press, Oxford(1952) |
| Taylor (1959) | J.Taylor, "Solid Propellent and Exothermic Compositions," Interscience, NY(1959) |
| VanNostrand's Encycl (1958) | Van Nostrand's Scientific Encyclopedia, VanNostrand, NY, 3rd edit(1958) |
| Vogel, Inorg Analysis(1961) | A.I.Vogel, "A Textbook of Quantitative Inorganic Analysis," Longmans, Green & Co, London(1961) |
| Weingart, Pyrotechnics(1947) | G.W.Weingart, "Pyrotechnics," ChemPublgCo, Brooklyn(1947) |
| Welcher(Vol & Year) | F.J.Welcher, "Organic Analytical Reagents," Van Nostrand, NY, Vol **1**(1947); **2**(1947); **3**(1947) and **4**(1948) |
| Wimpress,Ballistics (1950) | P.N.Wimpress, "Internal Ballistics of Solid Fuel Rockets," McGraw-Hill, NY(1950) |

# B

# ENCYCLOPEDIA of EXPLOSIVES and RELATED ITEMS

## Volume 2

## B

**B**(Explosif) An expl manufd for some time by Bergès, Corbin & Co, near Grenoble, France: Amm perchlorate 89 & NG 11%
*Ref:* Commission des Substances Explosives, MP 12, 18(1903-1904)

**B**(Poudre), also called *Poudre blanche* or *Poudre à solvant* (Formerly called Poudre V). A smokeless NC propellant (poudre sans fumée) developed ca 1884 by Paul Vieille and named after the first letter of Boulanger, who was General and Minister of War at that time. As the proplnt proved to be very suitable for rifled firearms, it was adopted by the French Govt for use in the Lebel rifle. It was also adopted for use in field guns. Slightly earlier and independently of Vieille, a similar proplnt was developed in Germany by Max von Duttenhofer and designated *RCP* (Rottweiler Cellulose Pulver) (Refs 1,2,3,10,11,13,14,16 & 17)

The original poudre B consisted of small, flat squares, pale yel or brownish in col, and having an odor of ethyl acetate, which was used as a solvent for NC. Its approx compn was $CP_1$ (coton-poudre n°1) (NC with 12.9 to 13.4%N; insol in eth+alc) 68.2, $CP_2$(coton-poudre n°2) (NC with 11.7 to 12.2%N; sol in eth-alc) 29.8 & paraffin 2% (Refs 1 & 2). The above formulation was modified several times and the resulting proplnts were known as *poudres BN* where N stands for 'nouvelle', meaning new (Ref 2). One such proplnt contained $CP_1$ 40, $CP_2$ 30, Ba nitrate 18, K nitrate 8, Na carbonate (or tannin) 2, residual solvent 1 & moist 1% (Refs 7 & 9)
In about 1890 all the ingredients, except NC and a solvent, were discarded and then later (in 1896-7) some amyl alcohol was incorporated to serve as a stabilizer. These proplnts were designated as **B(AM)** or **BAm** (see Vol 1 of this Encyclopedia p A395-L). As amyl alc proved to be unsatisfactory it was replaced with a small amt(0.5-2%) of DPhA. This is a satisfactory stabilizer which is still in use(Ref 2 & Ref 14, p249)
Poudres B existed in the following varieties:
a)*B(Am)*. See above
b)BC(Poudre B a canon de campagne). Powder B for a field gun(Ref 6, p601 & Ref 7). It is no longer in use
c)*BCNL*(Poudre B à canon, nitratée, lavée)(Powder B for cannon, with nitrate, leached). It was prepd by mixing 80 parts of NC gel with 20 ps of powdered K nitrate, followed by graining and drying. Then most K nitrate was leached with water. This treatment gave(after drying) a porous proplnt which was fast burning. It was used for short range mountain cannons and for blank fire(Ref 4,p228)
d)*BD*(Poudre B à diphénylamine). Powder B contg DPhA as stabilizer (Ref 2 & Ref 10,p308)
e)BF(Poudre B à fusil). Powder B for rifle. According to Vieille, this proplnt was less erosive than either Cordite or Ballistite (Ref 2, p295 & Ref 10,p388)
f)*BFNL*(Poudre B à fusil, nitratée lavée). Powder B for rifle with nitrate, leached. A porous, rapid-burning proplnt prepd in the same manner as BCNL(see item b)(Ref 4,p228)
g)*BFP*(Poudre B en pailletes pour fusil de guerre). Designation for a rifle proplnt in the form of leaflets, contg camphor and centralite (Ref 5,p282)
h)$BFP_1$(Poudre B en paillettes pour fusil de guerre). Powder B in the form of leaflets for use in military rifles. It contained some camphor(Ref 5,p282)
i)*BG*(Poudre B de guerre destinée a l'armée de terre). Powder B, military, destined for the Army. This proplnt was designated $BG_1$, $BG_2$, $BG_3$, $BG_4$ etc depending on the caliber of the gun in which it was used. For instance, $BG_4$ was used in the 120mm gun. It was made in the form of strips, 1.45mm thick and 18mm wide (Ref 6,p601). The higher the index, the slower is the propellant(Ref 15,p458)
j)*BGC*(Poudre B de guerre pour gros calibre). Powder B for use in large caliber guns(Ref 2, p297)
k)*BM*(Poudre B de marine). Powder B, Navy. This proplnt has been designated as $BM_1$, $BM_2$.....to $BM_{20}$, where the indices indicate the approx caliber of the gun for which the propellant is intended. For instance, the $BM_7$ was intended for use in the caliber 7 gun, such as

155mm(Ref 6, & Ref 10,326)
l)*BN*(Poudre B nouvelle). See above
m)*BNF*(Poudre B nouvelle, pour fusil). Powder B, new, for rifle(Ref 7)
n)*BN*$^3$*F*(Poudre B à fusil nitratée, pour exportation). Powder B for rifle, nitrate treated, for export(Ref 4,p226)
o)*BN 3F*. A current proplnt designed for use in smooth-bore hand weapons(Ref 14,p252)
p)*BNLM*. One of the older poudres B for small arms. It was quick-burning(Ref 5,p294)
q)*BRU*. Older poudres B stabilized with urea (Ref 5,p296)
r)*BS*(Poudre B succédannée de la poudre noire SP pour le canon de siège et de place). Powder B replacing black powder SP, for use in siege and fortress guns. It was also used during WW1 in 75mm guns(Refs 2a & 6)
t)*BW*. According to Mangini(Ref 11a), poudre BW consisted of $CP_1$ 40, $CP_2$ 30, K and Ba nitrates 26, Na carbonate 2 & volatiles 2%. Mangini(Ref 11a) also gives the compn of poudre B as follows: $CP_1$ 50-75, $CP_2$ 50-25 & DPhA (added) 0.5%. A mixt of ether & alcohol is used as a gelatinizer
Stettbacher(Ref 12) gives for the current poudre B: NC(13 to 13.4%N) 80 & NC(11.7 to 12.2%N) 20% with 1.5 to 2% of DPhA added, all blended with eth-alc as a gelatinizer
Method of manufg poudre B as practiced before WWII is described in: Ref 4,pp228-233; Ref 6, pp 580-601; Ref 9, pp 292-310 & Ref 15,p 458
*Refs:* 1)Daniel(1902), 50 2)Marshall**1**(1917),294-7 2a)Chevereau,MP **19**,168(1922) 3)Brunswig, Proj(1926),7 & 134 4)Pascal(1930),226 & 228-36 5)Desmaroux,MP**24**,282 & 294-6(1930-1931) 6)Vennin, Burlot & L écorché(1932),578-602) 7)Marshall **3**(1932),85 8)Stettbacher(1933),190 & 197 9)Pepin Lehalleur(1935),289-90 9a) P. Vieille,MP**27**,7-10(1937)(History of'poudre V', now known as 'poudre B'), 10)Davis(1943),258, 292-4,308,326 & 388 11)Pérez Ara(1945),438-9 &441 11a)Mangini,Explosive(1947),235 12)Stettbacher(1948),41 13)Vivas,Feigenspan & Ladreda 3(1948),96 14)P.Tavernier,MP **32**,244 & 250(1950) 15)J.Fauveau,MP **33**,458 & 463(1951) 16)Stettbacher, Pólvoras(1952),51 17)C.Belgrano,'Gli Explosivi', Hoepli,Milano(1952),109-10

**B**(Value). See Brisance Value of K ast

**$B_4$**. A Ger vehicle contg a demolition charge. It was used during WWII for destruction of enemy targets, such as bridges, pillboxes, etc. For more info, see PATR **2510**(1958),p Ger 11

**B4 or Type 2 Explosives.** Lt grey powdery mixts of TNAns 60 or 70 with Al 40 or 30% used in Japanese incendiary submarine gun shells. The props of the 60/40 mixt were:d 1.90 (cast), *power* by ballistic pendulum 64%(PA= 100%), *brisance* by copper cylinder crusher 82% (PA=100%), *explosion point* 300 to 505°, *impact sensitivity* with 5-kg wt 17cm(max for no explns) and *friction sensitivity* 60kg(max pressure between two rubbing surfaces)
*Ref*: R. A. Cooley et al, 'Japanese Explosives', PB Rept 53,048(1945)

**B77.** A kind of black powder used in the Russian artillery from 1877 up to the adoption of smokeless propellant *Pyrocollodion*(N=12.44%) developed by Mendeléev ca 1891
*Ref*: Dr M.M.Kostevitch, Buenos Aires, Argentina; private communication(1955)

**BA-107.** Polybutadiene-Acrylic Acid Composite Propellant for Rocket Motors developed by Thiokol Chemical Corp. Its compn and props are given in conf 'Propellant Manual',SPIA/M2 (1959), Unit No 572 **B(AM) or BAm**(poudre). See Vol 1,pA395-L

**Bachmann,Werner E** (1901-1951). An Amer chemist specializing in org synthesis. During WWII he developed for OSRD a new, efficient process for manufg cyclonite(RDX)
*Ref*: A.L.Wilds, JOC *19*,129-30(1954)(Obituary)

**Backblast.** Rearward blast of gases to the rear of recoilless weapons, rocket launchers and rocket-assisted takeoff units
*Ref:* Glossary of Ord(1959),28

**Backbreak.** When blasting hard rocks by several charges placed in boreholes, it is very important that the charges are fired in rotation, in pairs, in the proper sequence. If this order is not followed, poor breakage will result. Such improperly fired charges cause what is known as *backbreak*. In order to ackieve the proper rotational firing, delay caps are usually employed. More precise timing is obtained by using the so-called *DuPont Blasting Timer*
*Refs:* 1)Blaster's Hdb(1949),15 & 99 2)Blaster's Hdb(1952),111 & 241

**Backflash, or (Backfire, Breechflash or Flareback).** The flash produced at the breech of a gun when the breech is opened after firing a round. This is caused by the ignition (and

expln) of CO and hydrogen of combustion gases at the moment of their contact with oxygen of the air. If the temp of the gases is not sufficiently high to produce self-ignition, the back-flash may be caused by a piece of smoldering or burning residue of proplnt or bag left in the gun barrel after firing.

The presence of CO and hydrogen is explained by the incomplete combustion of the proplnt which is required in order to keep the temp in the barrel sufficiently low to avoid excessive barrel erosion. This is achieved by not allowing sufficient oxygen for complete combustion(to produce $CO_2$ and $H_2O$) in the formulation of the proplnt and by incorporating in the proplnt some cooling(flash-reducing) agents

Precautions must be taken to prevent the flareback from reaching the new proplnt charge, as well as to prevent burns to the gun personel. Certain guns are equipped with compressed air gas ejectors which expel the gases in the bore before the breech opened. Even when so equipped, it is essential that the bore be inspected for burning residue before the next round is inserted. If the gun is not equipped with a gas ejector, the new propelling charge must not be brought near the breech until a wet chamber swab has been used. Guns with muzzle brakes and semi-automatic closures tend strongly towards breech-flashing

Back-flash is practically negligible with small caliber guns (with fixed ammo) but can be very serious with large guns. (See also 'Muzzle Flash') *Note:* According to Stickland (Ref 4), the only reliable means of fighting the breech (and muzzle) flash is the use of a cool proplnt, such as Gudol, described in PATR **2510**(1958),Ger 81

*Refs:* 1)Marshall **1**(1917), 318 2)Marshall **3** (1932),93 3)Hayes(1938),35-6 4)O.W.Stickland PB Rept **925**(1945),83 5)Glossary of Ord(1959), 28,49 & 119

**Bacon, Roger** (1214?-1292). An English alchemist, considered to be one of the inventors of a compn similar to black powder. Made numerous other contributions in various branches of science

*Ref:* F.J.Moore, 'A History of Chemistry', McGraw-Hill,NY(1939),25

**Bacteria and Mold Action on Nitric Esters and on Smokeless Propellants.** Influence of microorganisms upon stability of NC was studied as early as 1896, when Bokorny(Ref 1) stated that NC is utilized by both bacteria and fungi (such as encountered in contaminated water) as a source of carbohydrates and nitrogen. In his experiments a highly esterified NC was broken down in water contg bacteria & fungi together with small quantities of mineral substances needed by micro-organism. No decompn of NC took place, however, when experiments were conducted in distilled w. Malenkovic(Refs 2 & 3) stated that neither NC nor NG is directly decompd by mold but if one or both of them are stored incontact with substances attacked by mold(such as paper), they are also decompd. The same investigator claimed that NG alone is definitely a mold poison, but he was not sure about NC. Jacqué(Ref 4) stated that water used for washing NC is the principal source of bacteria which causes deterioration of NC. He found that micro-organisms do not live in dry NC but thrive in moist material. One of his findings was that compressed guncotton with 15% moisture was infected with reddish or greenish bacteria without, however, appreciable changes of NC in weight, N content, or stability. NG and NG-expls(such as dynamites) did not support org life and attempts to innoculate such media failed. Some algae and aquatic plants yielded decompn products(such as oxalic acid, etc) which caused decompn in nitric esters under the action of heat. Fabel(Ref 5) also pointed out that NC can serve as a source of nourishment for bacteria. Kaye(Ref 6) studied at PicArsn, by means of an electron microscope, the action of micro-organisms on grains of the propellant M8, stored for some time in a magazine. The compn of M8 was: NC(N=13.25%) 52.15±1.50, NG 43.00±1.50, DEtPh 3.00±0.50, K nitrate 1.25±0.25 & Et Centr 0.60±0.20%. It was found that surfaces of grains of proplnt exhibited contamination by micro-organisms which ranged in shape from spheres and cylinders to rods and squares. Penetration of these bacteria beyond the surface was also apparent. The contamination probably resulted from bacteria encountered in water used during manuf of M8 by the slurry method

*Refs:* 1)T.Bokorny, ChemZtg **20**,985-6(1896) 2)B.Malenkovic,MitteilGegenstände-Artil-Geniewesen **1907**,599-615 & CA **1**,2411(1907) 3)B. Malenkovic,Revue d'Artillerie **1908**,261(1908) & CA **3**,248(1909) 4)M.Jacqué, SS**5**,81-2(1910) & CA **4**,1546(1910) 5)K.Fabel,"Nitrocellulose",F.Enke Verlag,Stuttgart(1950),pp 115-6(Verhalten gegen

Bakteria und Pilze) 6)S.M.Kaye,PATR **2210**(1955) (An electron Microscope Examination of the Surfaces of M8 Propellant)

**Bacteriological or Biological Warfare.** See under Chemical, Biological and Radiological (CBR) Warfare

**Badische Aniline-und Sodafabrik(BASF).** A German concern, one of the biggest in the world. It formerly manufd various chemicals, including some explosives. Its history is described in the booklet entitled: 'BASF schreibt Geschichte',Ludwigshaven(1952),29pp

**Baelinites.** Mining expls contg AN 85-95 & TNT 15-5%(*Refs* 1 & 2). *According to* Ref 3, the baelinite contg AN 93 & TNT 7% was safe against firedamp
*Refs:* 1)Gody(1907),712 2)Colver(1918),249 3)Pepin Lehalleur(1935),352

**Bagasse** is the dried crushed sugar cane residue from which the sweet juice has been extracted. When obtained from sugar cane the crude bagasse contains ca 88% water. The dried material consists of ca 50% cellulose, 25% lignin and 25% of pentosans, hemicellulose, gums and non-sugars. The cellulosic portion is principally alpha-cellulose with a fiber length of ca 3.5mm and is readily isolated by the alkali or sulfate processes used for manufg woodpulp. Bagasse represents an excellent source of readily available cellulose for chemical processing and can be used in the manuf of cellulose derivs including NC. In the powdered form it can be used as a fuel and absorbent in dynamites

Dry distn of bagasse produces acetic acid and methanol, leaving charcoal as a residue
*Refs:* 1)L.W.Babcock, USP 1741146(1929) & CA **24**,1220(1930) (Bagasse together with NG & AN in dynamites) 2)E.I.duPont de Nemours,BritP 375824(1930) & CA **27**,3335(1933)(Bagasse for use as an absorbent for NG or similar liq expls) 3)J.de la Roza,Sr,Mem 14th ConfAnual, AsocTecAzucar,Cuba **1940**,331-2 & CA **35**, 5317(1941)(Prepn of product contg 99% of alpha-cellulose by special treatment of sugar bagasse; this cellulose is more easily nitrated, washed and dehydrated that linters) 4)Kirk & Othmer **2**,(1948),271-3(Bagasse) 5)L.F.Wiggins,Chem & Ind **1949**,555-6(Bagasse as a raw material for chemical industry) 6)C.J.West, 'The Utilization of Sugar Cane Bagasse for Paper,Board,Plastics and Chemicals', Technological Rept Series No 8,Sugar Research Foundation,Inc,NY(1952), 202pp

**Bagasse Pith** is the loose spongy tissue occupying the center of the sugar cane. It has been used in expls(Ref 2). Chapman(Ref 1) patented its use with NC-NG mixts to make low density gelatin-dynamites
*Refs:* 1)F.F.Chapman,USP 1992189(1935) & CA **29**,2745(1935) 2)Bebie(1943),30

**Bags for Propelling Charges.** See Cartridge Bags

**Baka(Suicide) Bomb or Kamikaze**(The name Baka, meaning stupid, was given by Americans). It was a piloted rocket-propelled bomb used by the Japanese Navy during WWII. It could be launched from any twin-engined plane at a distance of 20-30 miles from the target. Its over-all length was 19'10", wing spread of 16'5", wt 4000, inclusive of a 2645-lb warhead in the nose. It had a down-speed of around 550 mph. Its warhead was filled with 1135 lb of TNAns (Type 91 Explosive). The proplnt (6 sticks) consisted of: NC 59.9, NG 26.9, MNN 6.1, Et centr 2.9 & volatiles 1.3%
*Refs:* 1)Anon,Army Ordn **29**,382(1945) & CA **30**, 116(1946) 2)Anon, 'Japanese Explosive Ordnance', TM **9-1985-4**,Washington,DC(1953),116-18 3)Meriam-Webster's (1961),1231

**Baked Powder**(Anhydrous Powder) was prepd ca 1873 by the Russian Colonel Wiener by pressing the ingredients of black powder at 120°. By this method a more homogenous and compact mass was obtained than in ordinary BkPdr because the sulfur melted and was distributed more uniformly betw the K nitrate and charcoal. As this method of manuf was dangerous it was abandoned in 1878
*Ref:*Daniel(1902),808

**Bakelite.** A synthetic resin obtained by the condensation of formaldehyde with phenols. Used as a plastic in many industries(Ref 2). Was patented by the Italian Co for making bodies of projectile fuzes(Ref 1)
*Refs:* 1)SocItalPolveriEsplodenti,BritP 298948 (1927) & CA **23**,3102(1929) 2)Kirk & Othmer **10** (1953),801

**Bakewell & Hurst** patented in 1896 & 1897 a

method of loading projectiles with NG and then freezing it in order to render it insensitive during transportation and firing. Inside such project was placed a special device which melted the NG during the flight thus rendering it again sensitive just before bursting. These projects were dangerous to handle because NG sometimes exploded from shock or friction
*Ref:* Daniel(1902),50-1

**Bakufun**(Exploding Powder). A Jap mixt of MF, K chlorate & Sb sulfide used during WWII in some initiators
*Ref:* OpNav **30-3M**(1945),25

**Bakuhatsu-sei**(Jap). Blasting Gelatin

**Balanced Dope.** See under Dope

**Balistita** (Span). Ballistite

**Balistite** (Fr & Ital). Ballistite

**Ball and Disk Machine.** See under Impact Tests

**Ball Drop Test.** See Vol 1,pA573-L

**Balle** (Fr). Bullet; ball

**Balle de fusil** (Fr). Rifle bullet

**Balle perforante** (Fr). AP bullet

**Balle traceuse** (Fr). Tracer bullet

**Ball Grain Powder.** See Ball Powder

**Ballista or Balista.** A device first used by the Romans and then by the Greeks, as early as the 1st century AD, for hurling very heavy missiles (Such as stones, beams, etc) against fortifications, buildings, etc. The motive power was supplied by tightly twisted hemp, sinews of animals or raw hide. There were two types of ballistas: one throwing missiles at high trajectories from the end of a rotating arm (See illustration in Ref 1, p8), the other working on the same principle as a large catapult (See Fig 1 in Ref 3)
*Refs:* 1)Greener(1881),8 2)Farrow's Milit Encycl **1**(1895),12g 3)EncyclBritannica **5**(1952),24(under Catapult) & **8**)(1952),453(under Engines of War) 4)Macmillan'sEncycl **1**(1959),717

**Ballistic Cap.** A forged steel cap used on armor-piercing projectiles to protect the point from shattering upon impact with target, such as steel plate. By creating an initial stress in the plate at impact and having a greater bite at angles of obliquity, it lessens possible ricochet and permits better complete penetration by the projectile(Ref 2). Various types of ballistic caps used in US artillery are shown on Figs 1, 2,6,etc of Ref 1. The ballistic cap is usually covered with a *windshield*(qv) (See also Vol 1, pA483-L under Armor-Piercing Projectile)
*Refs:* Anon, 'Artillery Ammunition', TM 9-1901 (1950),5,8 & 12 2)A.B.Schilling,PicArsn; private communication(1960)

**Ballistic Homogeneity of Poudres B** was discussed by J.Fauveau,MP **33**,461-2(1951). If samples of proplnt taken from any part of a lot possess identical ballistic properties, the ballistic homogeneity is considered to be satisfactory

**Ballistic Measuring Methods and Ballistic Tests.** In order to determine the suitability for military purposes of propellants, explosives, projectiles, weapons, etc, it is required that tests be conducted, using appropriate devices. As a final test, firings are conducted on a full scale at proving grounds

For instance, a proplnt to be ballistically suited for a certain weapon, must provide a prescribed *muzzle velocity*(qv) at a *pressure* below a prescribed maximum, which has been previously detd as safe for the weapon in question. In order to test the suitability of a proplnt, a series of rounds is fired beginning with small proplnt chges. These are increased gradually until a muzzle velocity is reached which is equal to or sl higher than that desired, or until the max press is exceeded. During the test, samples of 'Standard' proplnt are also fired alternately with the test proplnt for the purpose of calibration. Pressures and muzzle velocities for the test proplnt are plotted as functions of the wt of the chge. The chge *(optimum charge weight)* which will give the desired muzzle velocity is detd from the resultant curve. A series of uniformity tests, using the optimum charge weight, is then run during which the variations of velocity and mean pressure must fall within narrow prescribed limits if the proplnt is to be accepted(Ref 2)(See also under Muzzle Velocity Determination: Pressure Meas-

urements, and Terminal Velocity Determinations)

These tests, when conducted in different weapons, may also serve as ballistic tests of the weapons

As examples of ballistic tests for explosives may be cited brisance, power, velocity of detonation tests, etc. Some of these tests are briefly described under Physical Tests, Vol 1, p VIIff, of this Encyclopedia, others will be described later. Ballistic tests for shells, bombs, rockets, grenades, etc may include fragmentation characteristics, penetration in armor (or concrete), etc

Following are some refs on ballistic measurements and tests:
1)C.J.Cranz, 'Lehrbuch der Ballistik', Springer, Berlin,vol **3**(1927) and Ergänzungsband(1936) 2)T.Hayes, 'Elements of Ordnance',Wiley,NY (1938) 3)M.Meyer, 'The Science of Explosives', Crowell,NY(1943) 4)Anon, 'Ordnance Proof Manual' ORD-M608-PM(1946) (Ballistic tests used by the US Ordnance Installations are described in detail) 5)I.Cohen, 'Ballistic Testing of Rockets', Lecture delivered at PicArsn,14 March 1947 6)W.D.Chesterman, 'Photographic Study of Rapid Events', Clarendon Press,Oxford(1951) 7) H.Stadler et al, Explosivst **1954**,144-8 & **1955**, 1-6 (Measurements in internal ballistics) 8)P. Naslin & J.Vivié, 'Photographie et Cinématographie Ultra-Rapides',Dunod,Paris(1956) 9) J.F.Roth, Explosivst **1957**,161-76(25 refs) (Ballistic measuring methods)

**Ballistic Missile.** Any missile that is guided during powered flight in the upward part of its trajectory and becomes a free-falling body in the latter stages of its flight toward its target. It contains guided mechanisms, but is distinguished from a guided missile in that it becomes a free falling body, subject to the laws of ballistics, as it descends through the atmosphere. The missile is designed to travel in the outer atmosphere or beyond it before plunging towards its target. The German WWII missile V-2 and US Polaris, Pershing and Thor are examples of ballistic missiles (Refs 3,10 & 14)
*Refs:* 1)U.D.Rose,'Die unheimlichen Waffen, Atomraketen über Uns',Schild Verlag,München -Lochhausen(1957) 2)A.F.E:son Scholander, 'Robotvapen', Folkvörsvaret Förlags AB (Sweden)(1958) 3)Interim Glossary Aero-Space Terms, Air University,Maxwell Air Force Base, Alabama(1958),5 4)K.F.Ganz,Edit,'The United States Air Force Report on the Ballistic Missile', Doubleday,Garden City,NY(1958) 5)H.E. Newell,'Guide to Rockets,Missiles and Satellites',Whittlesey House,NY(1958) 6)R.B.Dow, 'Fundamentals of Advanced Missiles',Wiley,NY (1958) 7)J.W.Herrick,Ed,'Rocket Encyclopedia Illustrated',Aero Publishers,Inc,Los Angeles 26, Calif(1959) 8)C.E.Davis, 'The Book of Missiles',Dodd,Mead & Co,NY(1959) 9)Editors of Air Force Magazine, 'Space Weapons; A Handbook of Military Astronautics',Praeger,NY(1959) 10)Glossary of Ord(1959),30 11)K.F.Ganz, 'Nuclear Flight',Duell,Sloan & Pearce,NY(1960) 12)F.I.Ordway & R.C.Wakeford, 'International Missile and Spacecraft Guide',McGraw-Hill,NY (1960) 13)A.Ball,'Ballistic and Guided Missiles', F.Müller,London(1960) 14)U.S.Military Standard MIL-STD-444,'Nomenclature and Definition in the Ammunition Area(1961),pp8-9 15)E.Burgess, 'Long-Range Ballistic Missiles',Chapman & Hall,London(1961)

**Ballistic Modifiers for Cast Rocket Propellants** are discussed in the National Lead Co Repts for Project TU-2,Contract DA 30-069-501-ORD-2005(Conf)

**Ballistic Mortar Test.** A brief description is given under Physical Tests,pVII in Vol 1 of this Encyclopedia. See also J.Taylor & J.H. Cook, J.SciInstruments **26**,266-8(1949) (Improved operation of the ballistic mortar for detg the 'power' of HE's)

**Ballistic Pendulum Test** is briefly described under Physical Tests, pp VII-VIII in Vol 1(See also A.Schmidt,Explosivst**1962**,23-34)

**Ballistic Pendulum Chronographs**(Ballistischependel-Chronographe in Ger) are devices in which projectiles of a certain weight strike the lower part of a pendulum causing it to swing. The greater the swing, the greater is the velocity of the projectile. The theory in the design of these devices is based on the idea of Cassini (1707), but it was Robins(1740), and Hutton (1775) who constructed the first apparatus. Considerable work on the improvement of the apparatus was done in France. The resulting device of Didion-Morin-Piombert was used successfully, beginning in 1836, for many years. Another apparatus of this kind was that of Cheval-Minarelli-Fitzgerald, invented in 1901

Ballistic pendulum chronographs are not the same as Pendulum Chronographs(qv)

*Ref:*Cranz **3**(1927),39-51

**BALLISTICS**(Balistique, in Fr;Ballistik, in Ger) Ballistics is the science that treats of the motion of projectiles and is a particular branch of Applied Mechanics

Ballistics has two major divisions:
*A. Interior or Internal Ballistics*- the study of Motion of the projectile while still in the bore of the gun. This includes the consideration of the mode of combustion of the propellant, the pressure developed in the chamber, the velocity of the projectile along the bore, etc
*B. Exterior or External Ballistics*- the study of the motion of the projectile after it leaves the muzzle of the weapon

The branch of ballistics called *Terminal Ballistics* is concerned with the forces operating at the end of the projectile trajectory, that is, at the target. This is really a part of external ballistics, although this branch is sometimes referred to as a division (Ref 37)

Following is a selected list of books and papers on ballistics:
1)A.Brynk,'Interior Ballistics', translated from Rus by J.B.Bernadou, USGovt Printing Off,Washington,DC(1904) 1a)G.Schweikert,'Innere-Ballistik',Leipzig(1923) 2)C.J.Cranz,'Lehrbuch der Ballistik',Springer,Berlin,vols 1-3(1925-1927) and Ergänzungen(1936), English translation by the division of Armor and Ordnance, NDRC(1944-1945) (Mimeographed) 3)Gen P.Charbonnier, 'History of Ballistics',MAF **7**,1227(1927) 4)G.Bruno, 'Corso Teorico-pratico di Balistica Esterna',Arti Grafiche Castello, Torino (1934) 5)J.N.Bingen, 'La Technique de l'Artillerie', L'Ecole Royale Militaire de Belgique,Bruxelles,Vol 1, 'Balistique Intérieure'(1935) and Vol II, 'Balistique Extérieure' (1936) 6)T.Hayes, 'Elements of Ordnance', Wiley,NY(1938),65,96 & 397-468 7)H.Schardin, 'Beiträge zur Ballistik und technischen Physik', Barth,Leipzig(1938) 8)R.Winter,MAF **18**,775-862 (1939); **19**,3-75 & 199-270(1940); **20**,163-214 (1946) (Interior Ballistics) 9)H.Athen, 'Ballistik,' Quelle & Meyer,Leipzig(1941) 10)T. Vahlen, 'Ballistik',W.de Gruyeter,Berlin(1942), reprinted by Edwards Bros,Ann Arbor,Michigan (1945) 11)J.M.J.Kooy & J.W.H.Uytenbogaart, 'Ballistics of the Future with Special Reference to the Dynamical and Physical Theory of the Rocket Weapons',Technical Pub Co,Haarlem (1947) 12)M.E.Serebryakov, 'Interior Ballistics', Oboronizdat,Moscow(1949),translated by Dr. V. Nekrassoff, Contract NOrd 10260(1954), Washington, DC, p 22 13)Anon,'Exterior Ballistics', USMilAcad,West Point,NY(1949)(Pamphlet) 14)R.N.Wimpress,'Interior Ballistics of Solid Fuel Rockets',McGraw-Hill,NY(1950) 15)J. Corner,'Theory of Internal Ballistics of Guns', Wiley,NY(1950) 16)H.P.Hitchcock,'Handbook of Ballistic and Engineering Data for Ammunition', Ballistic Research Lab,Aberdeen,Md, vols **1 to 4**(1950) 17)F.R.Hunt,'Internal Ballistics',Philosophical Library,NY(1951) 18)Anon 'Interior Ballistics',USMilAcad,West Point,NY (1951) (Pamphlet) 19)Anon,'Terminal Ballistics', USMilAcad,West Point,NY(1951) (Pamphlet) 20)SACMS(Scientific Advisory Council,Ministry of Supply) 'Internal Ballistics', Philosophical Library,NY(1951) 21)Anon,'Fundamentals of Ballistics',Special Text ST **9-153**, The Ordnance School,Aberdeen PG,Md(1952) 22) Encyclopedia Britannica **2**(1952),999-1006 23)E.J.McShane,J.L.Kelly & F.V.Reno,'Exterior Ballistics', Univ of Denver Press(Mimeographed)(1953)(843pp) 24)M.Garnier,'La Balistique Extérieure Moderne en France',Imprimerie Nationale,Paris(1954).Reprinted from MAF **28**, 117-234(1954) 25)Anon,'Elements of Armament Engineering', USMilAcad,West Point,NY(1954), Part 11,pp 85-110(Interior Ballistics);111-135 (Exterior Ballistics);136-44(Bomb Ballistics); 145-64(Instrumentation) and 165-6(Terminal Ballistics) 26)W.Bevelander,'Uitwendige Ballistiek',Uitgeverij Excelsior,s'Gravenhage (Holland)(1954)(Exterior Ballistics) 27)P. Tavernier,MAF **29**,73-158 & 513-618(1955); **31**,303-390(1957); **32**,37-109 & 591-695(1958) (Interior Ballistics, Theoretical) 28)H.L.Dryden 'Ballistics Research',Ordn **40**,893-7(1956) 29)P.Curti,Explosivst **1956**,269-76(A mechanical solution of interior ballistics) 30)G.Seitz, Explosivst **1956**,248-56, **1957**,7-11,53-7 & 187-94)(Computations pertaining to internal ballistics) 31)Collier's Encyclopedia **3**(1957), 33-6 32)R.Schmidt, 'Praktische Ballistik für den Artilleristen,Erste Einfuhrung in die Aussenballistik', E.S.Mittler,Frankfurt a/M(1957) 33)L.Besse,MAF **31**,391-446,593-625 & 939-1016(1957); **32**,505-36 & 697-743(1958); **33**,143-239, 269-336, 555-608 & 807-926(1959); **34**,13-110(1960)(Course of Exterior Ballistics) 34)L.Davis,J.W.Follin,Jr & L.Blitzer, 'Exterior Ballistics of Rockets', Van Nostrand, Princeton,NJ(1958) 34a)H.Athen,'Ballistik', Quelle & Meyer,Heidelberg(1958) 35)W.C. Nelson,Edit,'Selected Topics on Ballistics',

NATO-AGARD,Pergamon Press,NY(1959) 36)R.E.Kutterer,'Ballistik',Vieweg,Braunschweig(1959) 37)Glossary of Ord(1959),p30 (under ballistics)

**BALLISTITE** (Balistita in Span, Balistite in Fr,Ital & Port, Ballistit in Germ & in Rus, Barisutaito in Jap). A successful double-base propellant invented by A.Nobel of Sweden in 1887-1888. One of the earliest compositions (patented in 1888) contained NG 50-60 & dry, pulped, sol NC 50-40%. The fibrous structure of NC in this proplnt was destroyed, not by the use of a vol solvent(as in the case of the contemporary poudre B), but by dispersing the NC in the powerful liq expl, NG, which functioned as a non-volatile gelatinizer for the NC. In order to facilitate the dispersion of NC in NG, some benzene was added to the NG. After mixing in a kneading machine, the benz was allowed to evaporate and the remaining material was passed several times through warm rolls until it became homogeneous. Then the sheets were rolled until the desired thickness was obtained and cut into required shape and size. The use of NS(nitrostarch) for part of the NC and the addition of pulverized chlorate or picrate were also mentioned in the patent of 1888

In Nobel's patent of 1889, the use of camphor and volatile solvents(such as benz) was eliminated and the gelatinization was effected by mixing NC with NG under w, heating to $80^{\circ}$, then rolling and cutting as above. In a modification of this process the gelatinization was hastened by using an excess of NG and subsequently removing it by means of 75% methanol

In the same year, Lundholm and Sayers, also of Sweden, proposed facilitating gelatinization by bubbling compressed air through a slurry of NC, NG and stabilizers(such as aniline & chalk) in hot w. Under these conditions a dough was formed which was passed several times betw rolls heated to $50\text{-}60^{\circ}$. Then the sheet(carpet) was cut into square flakes and these were glazed with graphite and blended. DPhA was used as a stabilizer in later formulations of ballistite

As Ballistite proved to be very successful as a proplnt, it was adapted by several countries, among them Germany and Italy, while some other countries preferred single-base proplnts(*poudre B* of Vieille in France and *Pyrocollodion* of Mendeléev in Russia). At the same time GtBrit adopted *Cordite*, which is, strictly speaking, a modification of early Ballistite in which NG together with a volatile solvent was used. The US at first adopted a double-base proplnt, *Indurite* invented by Munroe, but later switched to Bernadou's single-base proplnt *Pyrocellulose* which was really a modification of *Pyrocollodion*

The so-called *solventless propellants* used in great quantities at the present time are really modifications of the Ballistite of Nobel

The Ballistite contg 50-60% of NG caused considerable erosion of gun barrels because of its extremely high burning temp due to the presence of a large amt of NG. For this reason, later formulations of Ballistite were made with smaller amts of NG, partly replacing it with the 'cooler' DNT. As this change involved decrease in oxygen content, part of the sol NC(ca 12%N) was replaced with insol NC(ca 13%N), which contains more O. The resulting proplnt was called *Super-attenuated Ballistite.* Its compn was NG 25, DNT 15, 12%N NC 30 & 13%N NC 30%. It was used in WW1 by the French & Italians and proved to be nearly flashless

Ballistites have been used as proplnts not only in cannon, but in howitzers, mortars and in rockets as well

Following are some examples:

*Brazil*(Balistite). Admiral of Brazilian Navy Alvaro-Alberto detnd some props(including erosiveness) of several proplnts used in Brazil among which was the Ballistite contg 50% NG & 50% NC(Ref 10)

*France*(Balistite), designated *BALn*, consisted of $CP_2$(NC contg ca 12%N) with at least 40% of NG; it was used in the form of square plates of various thicknesses; the thinnest of them was used for launching bombs and grenades (Ref 4). Two formulations of Fr Attentuated Ballistite are described in vol 1 of this Encyclopedia,p A506-L, under ATT

*Germany*(Ballistit). An older compn, *WPC/89* (Würfelpulver/89), is described in PATR 2510 (1958), p Ger 11. Brunswig(Ref 2) lists the compn: NG 40, collod cotton 49, MNN 5, vaselin 5.5 & moisture 0.5%. According to Pepin Lehalleur(Ref 6), this proplnt was used in Norway for rifles.

*Italy*(Balistite). Several varieties have been used: a)*Balistite normale o ordinario*(Normal or Ordinary Ballistite), also called *balistite al* 50%, such as manufd during WWII by the Società Dinamite Nobel, Avigliana, contained: NG 49.6 ±2, NC(N=11.9±0.3%) 49.8±2, DPhA 0.5±0.3,

graphite 0.2±0.15 & moisture ca 0.5%. Its props are given in Refs 13,18 & 19. Although this proplnt was very erosive, it was used on account of its high ballistic strength; b)*Balistite a basso titolo*(Ballistite of low Strength), also called *balistite al 42%*, such as manufd by the Società Dinamite Nobel, Avigliana, contained: NG 42.5±1.5, NC(N=12.0±0.25%) 56.5±2, Et centr 1.0±0.5, graphite 0.2 & moist 0.5%. Its props are given in Ref 13; c)*Balistite attenuata* (Attenuated Ballistite), also called *polvere CG13*, contained NG 25-26, NC(blend of collod cotton & guncotton) 60 & DNT 16-15% with a stabilizer added (Ref 19); d)*Balistite attenuata all'acetilcellulosa*(Attenuated Ballistite Containing Acetylcellulose), developed by Giua(Ref 18,p 157) at the Società Dinamite Nobel, contained: NG 25, NC 60, acetylcellulose 10 & Et centr 5%; e)*Balistite al 60%* contained NG 60 & NC 40% with a stabilizer(added) 1-2%(Ref 3). It was too erosive for use as a propellant in guns, but it proved to be very suitable as a bursting charge in some smaller caliber projectiles such as 37/40mm HE and 37/40mm HEAP(Refs 14 & 21,p73) e)*Filite* - the name for Ballistite in the form of cords(Ref 1)

*Japan*(Barisutaito). No info about its uses

*Russia*(Ballistit). No info on the use of Ballistite at our disposal. Burning characteristics of Ballistites were determined recently in Russia by Pokhil et al(Ref 24)

*Spain*(Balistita). According to Sancho(Ref 7), the Spanish and Italians used *balistita IE*, which contained more than 50% of NC. Its props are given,(but no compn) by Vivas, Feigenspan & Ladreda(Ref 17,p 89) who state that balistita is manufd in Spain by the Sociedad Anónima de Dinamita de Galdácano(Bilbao). When balistita is made in the form of tubes it is called *tubelita*

*Sweden*(Ballistit). Early Ballistites of Nobel and of Lundholm & Sayers are described at the beginning of this section, but no info is at our disposal regarding current Ballistite. Stettbacher(Ref 5) describes the method of manufg Ballistite using machinery of the famous firm of Aktiebolget Bofors Nobelkrut(See Bofors Industries)

*Switzerland*(Ballistit). Stettbacher(Refs 16 & 20) briefly describes the manut of Ballistites contg 40-50% NG and 60-50% collodion cotton. He also states that Ballistites are used as rocket propellants(Raketen-Treibmittel)

*USA*(Ballistite). According to TM **9-1904**(1944), p 96, the Ballistite used as propellant in trench mortars and shotgun shells contained NG 39, NC 60, DPhA 0.75 & graphite(coating) 0.25%. Armament Engrg (Ref 22) gives for Ballistite used for rockets: NG 43, NC 51.5 & additives 5.5%. This seems to be similar to *Ballistite JP 204* developed by Aerojet Engineering Corp, Azusa, Calif which contains: NG 43.0, NC(13.2%N) 51.6, K nitrate 1.4, diethylphthalate 3.25 & DPhA 0.75%. To this was added 0.16% of methyl cellulose(Ref 15). Rinkenbach(Ref 11a) reported that thermal stability of Ballistite contg NC 69.25, NG 30.5 & DPhA 0.25% with graphite coating, tested at Pic Arsn, was satisfactory

In Ref 23 is given the compn of *Ballistite JP*, which is practically the same as for JP 204 except that JP apparently does not contain methylcellulose but does contain 0.1% nigrosine dye

Compositions of the following ballistites used in rockets are given in Ref 15a:

*JPH*: NG 43.0, NC 54.5, EtCentr 1.0 & K sulfate 1.5%, with added methylcellulose 0.16 & carbon 0.10%

*JPN*:NG 42.9, NC 51.4, EtCentr 1.0, K sulfate 1.25, diethylphthalate 3.23, candelilla wax 0.02 & carbon 0.2%

*Refs*: 1)Marshall **1**(1917),301 2)Brunswig,Prop (1926),136 3)R.Molina, 'Esplodenti', Hoepli, Milano(1930),393-5 4)Pascal(1930),227 5)Stettbacher(1933),194 6)Pepin Lehalleur(1935),290 7)E.E.Sancho,'Química de los Explosivos', A.Aguado, Madrid(1941),337 8)B.H.Sage & W.N. Lacey, 'Extrusion of Ballistite Tubing and Rod', OSRD Rept **445**(PBL 27280)(1942) 9)W.W.Lacey & B.H.Sage,'Some Physical Properties of Ballistite', OSRD **947**(PBL 27283)(1942) 10)Alvaro-Alberto, AnaisAcadBrasilCienc **14**, No 4,341(1942) 11)Davis(1943),293-6 11a)Wm.H.Rinkenbach, PATR **1359**(1943),p2 and table 1(Surveillance and Heat Tests) 12)Pérez Ara(1945),413-14 & 442-3 13)J.D.Parsons,PB Rept **12663**(1945),15-16 14)Anon,USNavy,BurOrdn Manual OP **1668**(1946), 65 15)Aerojet Engineering Corp Rept **194**(1946), 15a)W.W.Farnum,USNaval Powder Factory Tech Rept No **15**,Indian Head,Md(1947) 16)Stettbacher (1948),42 17)Vivas,Feigenspan & Ladreda**3**(1948) 89 & 99 18)Giua,Dizionario, **2**(1949),157 & 178 (under Esplosivi) 19)Belgrano(1952),110-111 & 114 20)Stettbacher,Pólvoras(1952),52 21)Anon,'Italian and French Explosive Ordnance', TM **9-1985-6** (1953),65 22)ArmamentEngrg(1954),42 23)J.W. Herrick, Edit,'Rocket Encyclopedia Illustrated' Aero Publishers, Los Angeles,Calif(1959),40 24)P.F.Pokhil et al,DoklAkadN **135**,913-16 (1960) & CA **55**,26445(1961) Engl transln by Consultants Bureau,NY 11 in Chemical Tech-

nology Section, pp 193-5(5 refs)

**Ballistograph** is a device used for detg the velocity of projectiles in flight by a photographic method. It has been employed in conjunction with a micro-time-measuring device called in Ger 'Mikrozeitmess Instrument'. Both devices are described in Refs 1 & 2
*Refs:* 1)F.Duda, SS **19**, 100-4(1924) & CA **20**, 732(1925) 2)Cranz, **3**(1927), 329-335

**Balloons and Airships and Their Application in War.** A balloon is a bag of light non-porous material(such as paper, silk, rubberized cotton) filled with either heated air or a gas lighter than air(such as hydrogen or helium). The first balloon was constructed in France by the brothers Joseph & Jacques Mongolfier(1782)
The first balloons were so-called *free balloons* or *aerostats*. They could carry one or several persons, who rode in a basket attached by means of ropes underneath the balloons. When balloons are attached by cables to the earth or other mooring they are called *captive balloons*. These are often used as *observation balloons*. When a free balloon is sent aloft without passengers but with registering meteorological instruments, it is called a *sounding balloon*. A balloon used for investigation of high altitudes(such as 70,000 ft or higher) is known as a *stratosphere balloon*. The so-called *pilot balloon* is a small free balloon sent aloft to show direction of the wind. The *propaganda balloon* is a small sphere designed for spreading propaganda literature over enemy territory. This work is now accomplished almost exclusively by airplanes. A *kite balloon*, such as that of Drachen or of Capt Caquot, is an elongated form of captive balloon(commonly known as *sausage*) which is flown at a considerable inclination to the horizon in order to attain 'kiting' effect. The Caquot balloon was used by the British during WW1 for observation purposes, especially for spotting submarines (see below under Balloons, Applications in War)

Until about 1850 none of the balloons could be propelled or steered. The first balloon which could be successfully propelled and steered *(airship)* was constructed in 1851-2 in France by H.Giffard. It was equipped with a steam engine which rotated a propeller. The ship could move at a speed of 6mph. Higher speed was attained by later models, such as the one of P.Haenlein(Germany,1872) driven by an internal combustion engine; by A. & G.Tissandier(France, 1883) and by C.Renard & A.Krebs(France,1884), electrically driven

All the above-mentioned airships(also called *dirigibles)*and a very successful model constructed in 1898 by A.Santos-Dumont, a Brazilian inventor living in Paris, were *nonrigid*. The first *rigid-type* airship was built in Germany in 1897 by D.Schwarz. Its frame was of aluminum and it was filled with hydrogen. More successful was the rigid dirigible Zeppelin invented ca 1900

During the 1st decade of the 20th century, airship construction was carried on in most of the major countries and during WW1, airships were used by the Germans(who built rigid Zeppelins), by Brit & French(who built nonrigid dirigibles) and by Italians(who built semirigid airships)

After WW1 the Germans were prohibited from building airships(or airplanes), while Brit, Fr & Amer undertook extensive airship construction. The Amer firm of Goodyear Aircraft, Akron, Ohio, built many helium-filled nonrigid dirigibles, some of them for the US Navy, others for commercial purposes, such as advertising. About 1930 Brit and then in 1937 Fr abandoned the building of airships. Meanwhile the Zeppelin Co resumed its operation(1937). As a result of this, at the outbreak of WWII Germans had several modern Zeppelins ready for service, while the Allies had only a few nonrigid balloons, commonly known as *blimps*. In the course of WWII many more blimps were constructed for the US Navy and they were used successfully against Ger submarines. At the same time, the hangars and production facilities of the Zeppelin Co were destroyed by bombing and this ended Germany's airship activity

The post WWII period of aeronautical development began with only US and Russia engaged in airship construction and this only to a limited extent due to competition from airplanes
*Balloons, Application in War.* The first use of balloons by the military appears to date from the period of the French revolutionary wars(1789-99), when a 'corps of aeronauts' was formed and sent by the French in balloons over the Dutch and Austrian troops. The unexpected appearance of balloons had a demoralizing effect on the enemy and caused them to retreat. Later(1812), the Prussians employed balloons against the Napoleonic troops, but without great success. Balloons were also used for bombing purposes, as briefly described under Bombs, Historical(see under BOMBS)

In the Amer Civil War(1961-5) balloons were

used for observing and photographing the enemy's terrain and troops. Again, balloons were used during the Franco-Prussian War(1870-1) (such as for evacuating some Govt officials from besieged Paris), in the campaign against Tonking (1880's), in the Bechuanaland expedition(1880's), in the Spanish-American War(1898) and in the Russo-Japanese War(1904-5). With the advent of WW1, every major power began to pay more attention to war balloons. The captive balloons (*sausages* and *blimps*) were used in *balloon barrages*(qv) and for *observation* purposes. One of the methods used to spot a submarine was to attach, by means of a cable, a balloon manned by one or more observers in a basket below, to a destroyer or other ship going to sea for patrolling purposes. The use of power-driven balloons (*airships* or *dirigibles*) was not only for observation purposes but also, to a limited extent, for bombing(especially by Ger Zeppelins)

An ingenious application of balloons was made by the Japanese during WWII. They constructed ca 1000 paper balloons, spherical in shape and 33 ft in diam. The balloons were filled with hydrogen and could stay in the air for ca 1 week at a an altitude of ca 5 miles. A basket suspended underneath each balloon contained a bomb(incendiary or antipersonnel), two self-destroying devices, batteries activated by solar energy, several paper bags with sand(used as ballast) and devices for maintaining the balloon at the desired altitude and for bringing it down somewhere on the North Amer continent

The balloons were released from Japan one by one in the autumn of 1944 to be carried by easterly winds(prevailing at an altitude of ca 5 miles) toward Canada or the US. These balloons descended mostly in the Pacific coast area, such as Brit Columbia, Washington, Oregon & a few in Calif. Some balloons were carried to central or even eastern parts of Canada and the US. Total number of recovered balloons was ca 300, but many unquestionably have remained undiscovered because of the vastness of uninhabited territory on this continent. Some of the balloons travelled 6000 miles in 4 days at an average speed of ca 70 mph

The damage caused by bombs(incendiary or HE) carried by Japanese balloons was negligible(Ref 1)

*Refs:* 1)R.W.McKay,'Japanese Paper Balloons', Engineering Journal **28**,563-7(1945) 2)Merriam-Webster's(1951),209 3)EncyclBritannica(1952) **1**,464-71(Airships) & **2**,1006-10(Balloons) 4)Collier's Encycl(1957), **12**,378-83(under 'Lighter-Than-Air Craft') 5)Merriam-Webster's(1961), 167-8

**Balloon Barrage.** As originally developed in Gt Britain during WW1, a balloon barrage involved the release at a max height of 10000ft batteries of three *kite balloons (sausages)* of 10000cu ft capacity each, one at the center and one at each end of a horizontally floating cable 1000ft in length. From this was suspended, at regular intervals, a series of steel wires trailing earthward like flexible teeth in an enormous comb. An attacking airplane was thus forced either to rise above this contrivance or to dive below it. In the first case, the height would be too great to permit accurate bombing(at this time), while in the second case a plane would risk exposure to the effects of point-blank AA fire

With the advent of WWII, the barrage ceiling was increased to 15000ft and balloon barrages assumed new importance, especially in the defense of London

Similar 'sausages' towed singly by destroyers or merchant vessels, served as barrages in the defense of convoys passing through the English Channel because they rendered hazardous any attempt by hostile air raiders to carry out dive-bombing operations

*Refs:* 1)Anon,'Barrage Balloon Manufacturing', Manufacturers' Record **112**,36-7(1943) 2)Encycl Britannica **2**,(1952),1011 3)Collier's Encycl(1957) **12**,380(under 'Lighter-than-Air Craft')

## BALL POWDER or BALL GRAIN POWDER

(Globular Propellants or Olin Ball Powder) (Poudre sphérique in Fr; Pólvora W in Span, where W stands for Western; Perlpulver in Ger).

The process for the manuf of this proplnt was developed ca 1935 by Fred Olsen,Director of Research, Western Cartridge Co, Division of Olin Industries,Inc(now called Olin Mathieson Chemical Corp),East Alton,Ill. The process bears little resemblance to conventional methods of manufg proplnts and results in a product that is unique in the expls industry. The proplnt consists of small spheres, not larger than 0.030" in diam. Ellipsoids can be obtained by flattening the spheres by mechanical devices

Manuf of ball proplnt consists essentially of the following operations, as described in Refs 1-4:

**A.** *Shaping of Propellant*, also called *Granulating or Hardening*

a)NC of 12.4 to 13.4%N, previously pulped, subjected to a short preliminary boil and washed with cold water(to remove the bulk of acid), is placed on a 'nutsch' or a centrifuge to remove the bulk of the water. The slightly wet NC is loaded into drums and transferred from the NC plant to the 'ball powder plant'

*Note:* Instead of using straight NC, a mixt of NC and some reworked or deteriorated smokeless proplnt may be used. The grains of proplnt larger than 80-mesh must be previously reduced in size by treatment under water(buffered to ca pH 7.2) in a hammer mill. Treatment in w will remove the acidic decompn products of NC but will not remove the nitroso- or nitro- derivs of DPhA, if they are present. In this case, the addn of a larger amt of DPhA than usual would be required in subsequent operations

b)The NC is unloaded from drums into a sump and then, after mixing with an additional amt of w, the NC is pumped as a slurry into a closed, stainless steel, cylindrical jacketed vessel, known as *shaping tank*(capacity 3200 to 8400lbs of finished product). The vessel is provided with a vertical condenser for recovery of solvent vapors and a mechanical agitator which is driven through a Reeves variable speed drive by a motor situated in an adjoining room

c)The shaping tank is filled to a predetnd level with w contg some finely pulverized or pptd chalk, after which steam is introduced into the jacket and a volatile org liquid, such as ethyl acetate(which is a good solvent for NC but is immiscible with w), is added while the agitator is in motion. A small amt(ca 1% based on the final product) of stabilizer, such as DPhA, is usually added to the et acet before it is poured into the shaping tank

*Note:* The amt of et acet used should be such as to make a lacquer contg 15 to 25% of NC. The viscosity of this lacquer should be from 300 to 2500 secs at 25° by the Falling Ball Method. As the lacquer is lighter than w, it has the tendency to rise to the surface

d)After raising the temp to ca 50° and agitating for ca 30mins, all the NC goes into soln and the mineral acid(mostly sulfuric), which was tenaciously held by the NC fiber, is released. The agitation disperses the lacquer in the water phase (forming a quasi-emulsion) and washes the acid out. The fine particles of chalk, which are present in the mixt, neutralize the acid, leaving the neutral and stable NC dissolved in et acet

*Note:* The operations described above are applicable to any single-base proplnt. In order to prepare a double-base proplnt, the required amt of NG(or NG + NGc) in a suitable solvent is added at this stage of the process and dispersed uniformly throughout the quasi-emulsion. Substances like DNT, TNT, DBuPh, centralites, etc may be incorporated, if desired in the same manner as NG

e)The next operation, which consists of breaking down the lacquer into small spherical particles, is of utmost importance and requires skillful operators and ca one hour of time

f)With the agitator blades adjusted to shear off portions of the lacquer, and with the colloidal soln being agitated rather rapidly, a small quantity(1-2% of the total amt of ingredients) of an aq dispersion of a glue-like substance, such as starch, dextrin, gum-arabic, bentonite, animal glue, etc(called the 'protective colloid'), is added to the contents of the 'shaping tank'. As a result of this operation the NC lacquer is broken down into small spherical particles which are suspended in the water phase. If the protective colloid is not added, the grains of proplnt which form during stirring coalesce, forming a continuous gelatinous mass as soon as part of the solvent is removed

*Note:* The probable theoretical explanation of the formation of globules from the lacquer in the presence of a protective colloid is given by Olsen in Ref 1, pp 3-4 under 'Operation'

g)The size of the globules, and of the grains formed later, depends upon a number of factors: the grain size decreases with increase of rotor speed, with increase in percentage of protective colloid present and with decrease(within certain limits) of the inherent viscosity of the NC (viscosity of a given wt of NC in a given quantity of std solvent). Other factors, such as temp, agitation time, the shape of the agitator, the type and quantity of colloid added, and the rate of removal of the solvent, also influence the size of the grains

*Note:* Proplnts for various purposes range in finished sphere diam from 0.006" to 0.030", but for any particular proplnt, a rather close tolerance of sizes is desired. For instance, 0.006 to 0.010" for US cal .45 ammo; 0.010 to 0.014" for M-1 carbine; 0.015 to 0.030" for US cal .30(1906) ammo and 0.025 to 0.030" for US cal .50 and the 37mm cannon

h)The next opern, consisting of *debydration* of the

grains, is also of great importance because if it is not done properly the shape and density of the resulting grains will not be as required

The first step in this opern is to remove the small amt of w which is dispersed(or emulsified) in the globule of NC lacquer. Should this w be left through subsequent operations, the final ball grains would be porous and of low density. If, however, the w is removed before hardening of the grains, too high d material is obtained. The removal of w is achieved by dissolving an inorg salt(such as Na sulfate) in the water phase in order to set up an osmotic pressure gradient betw the w dispersed in the grains and the w in the tank. As a result of this, the w migrates from the grain through the NC lacquer(which acts as a semi-permeable membrane) to the Na sulfate soln in the tank

*Note*: As a rule, high d of grains can be achieved by dissolving a larger amt of inorg salt. The d may also be controlled by the temp and the time

i)When the grains have assumed the desired shape the next step is to remove the volatile liq(such as et acet) by distillation. For this operation a condenser is connected by a pipe to the upper part of the shaping tank and the temp in the tank is raised to the bp of the vol liq(69° for et acet). During the distillation period, the contents of the tank are kept agitated but at a lower rate than during the shaping period

*Note:*Rate of removal of the vol liq is a determining factor of grain size and care must be taken not to remove the liq too fast - otherwise hollow and porous grains, having the appearance of popcorn, are obtained. If, however, the liq is evap at too slow a rate and at a temp below its bp, extremely dense spheres are obtained. As a rule, the rate at which the vol liq can diffuse through the lacquer depends upon the viscosity and therefore upon the amt of vol liq present in the grain. The rate of diffusion must exceed the rate of removal of vol liq from the tank(by distn) or a hard skin(case) is formed around each globule. As the skin would not soften, the resulting grain would be hollow

j)To achieve the best results in distn, the solvent must be removed at a fairly rapid rate at the beginning and at a decreased rate later until the grains become case-hardened. After this, the rate of distn can be reasonably increased until the complete hardening of the grains

As an example, Olsen(Ref 1,p4) suggests starting the distn for high d proplnts at 68°(sl below the bp of et acet) and then raising the temp gradually (within 65 mins) to 72°. After case-hardening, the temp is raised to 95° and maintained until the vol liq is completely expelled

k)The distilled vol liq, mixed with w, passes from the condenser to a separator which is a cylindrical vessel provided with a gage and valves. Here, et acet collects at the top and thus separates from w which forms the bottom layer

l)At the end of the distn, the contents of the tank are allowed to cool to ca 50° and then are pumped as a water-slurry to a cylindrical tank (provided with an agitator) placed above the *rotary wet screens*. The resulting proplnt grains contain ca 1% of residual vol liq and the variation in diam of the spheres may be as high as 0.02"

*Note:* Due to the fact that a completely closed system is used in the shaping tank, the losses of vol liq are very small(ca 3%)

**B.** *Wet Screening.* In order to achieve closer size separation than could be done in the opns described above, the hardened balls are washed free of shaping tank liq(which consists of an aq soln of Na sulfate and all the protective colloid) and are then run through two or more rotary wet screens(such as the Trommel type) each of which separates two fractions: 'through' and 'on'. By using various series of screens, as many fractions as desired can be separated, most of which are usable directly in one grade of proplnt or another

After sizing, the aq suspensions of grains are stored in cylindrical, agitated storage tanks from which they can be pumped to the *coating still*, capacity up to 12000lbs

**C.** *Deterrent Coating.* If the proplnt prepd as above is used as such, it would be *degressive burning*. Inasmuch as the design of current weapons is based on the use of *progressive burning* proplnts, the initial rate of burning of balls must be reduced to such an extent that the proplnt will become more or less progressive burning. This may be achieved by coating the balls with a slow burning material, called deterrent, and the following method can be used:

a)To the agitated aq slurry of uncoated proplnt in the coating still is added the desired amt(such as 5-10%) of deterrent agent(such as DNT, dibutyl- or diphenylphthalate, etc) in the form of an aq emulsion. In the case of a material such as DNT, an emulsifying agent, such as saponin in w, can be used

b)With steam heat in the jacket, the charge is continually agitated until the deterrent has penetrated to the desired depth on the surface of the balls. This might take from 4 to 15hrs for

a 12000-lb batch
*Note:* Coating with a deterrent not only modifies the rate of burning of the proplnt, but it also renders the grains waterproof
c)The slurry of coated grains is pumped to the feed tank from where it can be sent either to the rolls(if the grain web is to be reduced in size) or directly to the top-feed filters(if the rolling operation is considered unnecessary)
*Note:* If it is desired to have the grains easily ignitable, they are coated with an accelerator (such as NG) instead of a deterrent. For this, a 20-30% soln of NG in alc or in benz is added to the contents of the coating tank and the slurry is agitated in the same manner as for coating with a deterrent and the desired amt(5-10% based on the dried wt of finished proplnt) of NG is added

**D.** *Wet Rolling.* Since the ballistic performance of a proplnt depends to a great extent upon the thickness of the web of the grains, it is important to have it as uniform as possible. As it is difficult to prep all the balls of exactly the same diam, the simplest way would be to select a batch with sl larger grain diam than required and then to slightly flatten the balls to form ellipsoids having their minor diam that corresponds to the desired web thickness. This is done because the time of combustion of an ellipsoid(or a similar flat grain) is the same as that for a ball of diam equal to the minor diam of an ellipsoid, provided that all the grains have the same compn and d. Ellipsoidal-grain proplnts are called in France *poudres sphériques ecrasées* and they were investigated by Tavernier(Ref 14) from the theoretical point of view

Rolling may be accomplished by passing a thick slurry of hot balls betw the faces of two highly polished, cylindrical rolls set together in such a manner as to reduce the web size so that the variation in diam is ca ± 0.001"
*Note:* If for some reason it is not desirable or convenient to roll the ball powder, the equal time of burning of sm all and large grains may be approx achieved by surface-treating the larger grains with an accelerator(such as NG) and the slower grains with a very slow deterrent, such as some phthalate

**E.** *Filtering and Centrifuging.* Before the proplnt is sent to the dryers, it must be dewatered to 8-15% $H_2O$ content(depending on the nature of the material) by passage either through a centrifuge or through a top-feed vacuum filter, such as the Oliver type

**F.** *Drying* is usually accomplished in continuous-belt dryers which are equipped with infrared lamps for heat supply

According to Olive(Ref 7), the damp proplnt is fed directly to the belt ( made of rubber or canvass, 48" wide and 80ft long, from a hopper contg an agitator. One hundred and forty 250watt infrared lamps are placed in 28 rows about 18" above the proplnt layer on the belt, being more closely spaced at the entrance end of the damp material than at the exit end. The ensemble is enclosed in a long chamber made of light metal panels, insulated and hinged, to serve as explosion hatches. A small amt of air, preheated by steam coils to ca 50°, flows counter to the proplnt movement to carry away the moisture. The heat is regulated in such a manner that the temp of the material is ca 72°, as shown by thermocouples riding on the surface of the moving layer of proplnt. With the above installation, 140lbs of proplnt can be dried in 1 hr with an av consumption of 0.196kw-hr per lb of dry proplnt. Drying time takes ca 1 hr

In the absence of an infra-red dryer, the propellent may be dried in conventional dryers(such as a tray dryer) but it takes a longer time(6 to 10hrs)
*Note:* In any case, drying of ball powder is much quicker than drying of conventional proplnts, which usually takes several days

**G** *Glazing.* In order to prevent the formation of an electrostatic charge, the proplnt is glazed with graphite. For this, the dried material is loaded into cans and transferred to the glazing bldg, where it is weighed in 1200-lb batches together with 2.5 to 6lbs of powdered graphite. Then each batch is rotated in a conventional *sweetie barrel* until a uniform black glaze and the desired moist content are obtained(which takes ca 2hrs)

**H.** *Dry Screening.* The glazed proplnt falls by gravity onto a conventional shaker screen, the purpose of which is not only to remove the oversize and undersize balls, but also any impurities which may have been picked up during previous operations

**I.** *Blending, Packing and Magazining.* Since each batch might have sl different props, the best practice is to thoroughly mix several batches so that the resulting blend will have intermediate props. By so doing, it is possible to obtain large batches(called lots) which are practically identical. The blending is done in a conventional *blender,* which consists of a tall tower in which the proplnt, first elevated to the top floor, grad-

ually descends by gravity through a succession of hoppers and knife edges where the flow is repeatedly divided and recombined

After blending, the proplnt is sampled, packed in a number of airtight cans and transferred to a magazine for storage. After inspection and acceptance tests, the proplnt is either used for loading ammo or left in storage until needed

*Note:* If a proplnt of uniform-sized balls does not possess the ballistic props required for a given weapon, materials of different grain size may be blended to secure such props(Refs 1-7 & 21-22)

The method of manuf described above may not be exactly the same as currently used because many modifications of the original Olsen method were proposed in the last 15 years

*Laboratory Method of Preparation of Ball Powder.* Take a wet, pulped NC(N=ca 12.6%) of known water content and weigh 60g(on a dry basis). Transfer to a 2-l fluted round-bottom, 3-neck flask, provided with a stirrer, and add 200ml distd w. Add, while stirring, 1g of 2-nitrodiphenylamine dissolved in 450ml ethyl acetate. Start to heat very slowly and add any other required ingredients, such as DNT. If the proplnt is intended to be double-base, the prescribed amt of NG or DEGDN, dissolved in a suitable solvent, is added at this stage. After raising the temp to ca 50° and agitating for about 30 mins, all the NC goes into soln forming a lacquer. After increasing the agitation to a rather rapid rate, add ca 120ml of 20% aq gum arabic soln or any other suitable protective colloid such as methyl cellulose. As the result of this operation, the NC lacquer is broken down into small spherical particles which remain suspended in the water phase. Since these particles contain some water, it must be removed before the next operation. For this, add to the slurry 50g Na sulfate dissolved in 200ml of distd w preheated to ca 60°. When the grains have assumed the desired shape, start to remove the et acet by distillation. For this, heat the slurry gradually to 69°(bp of et acet) while continuing the agitation and then finally heat to 72-75°. There is no necessity to heat the slurry to 95° as is done in plant operation

Cool the slurry to ca 50° and either centrifuge it or filter through a Büchner. Wash the balls with cold distd w to remove the protective colloid and Na sulfate, spread the proplnt on a filter paper and dry it

Following are some *advantages* in the manuf of ball powder over conventional proplnts:
a)The NC required to manuf ball powder does not need to be conventionally stabilized but simply sour-boiled and washed with cold w. Not only is freshly prepd NC suitable for ball powder, but also any discarded or reworked NC or smokeless proplnt may be utilized
b)The process of manuf is safer than for conventional proplnts because all the opns previous to drying are carried out under w and transfers of the NC are done by pumping it in a state of water slurry
c)Much simpler and less expensive equipment is used in the ball powder process than in manuf of conventional proplnts. No hydraulic presses are required
d)Shorter number of man-hours are required for production of unit wt of ball powder. The process is less expensive to operate than the conventional process for proplnt manuf
e)Since the operation involving a volatile liquid is conducted in a closed vessel, the losses of vol liq are very small(ca 3%)

The ball powder itself possesses the following advantages: a)It can be made either as single- or double-base proplnt using the same equipment b)It flows and screens very easily c)It possesses a higher thermal stability than any of the known extruded proplnts d)It possesses uniform d of loading and it is possible to secure, even by volumetric loading, charges in which the ballistic characteristics can be accurately controlled e) There exists the possibility of varying the d of grains when desired to secure slower or faster burning proplnts f)Less gun barrel erosion than for conventional proplnts g)The possibility of manuf of some types of rocket proplnts by mixing ball powder directly in the rocket motor with a non-volatile solvent and then allowing the thick slurry to set to a solid or semi-plastic mass

Following are some *disadvantages* of ball powder: a)Impossibility of producing balls larger than about 0.030" in diam. As such small grains are comparatively fast burning they are suitable only for smaller ammo up to ca 37mm b)Impossibility of making all grains of the same batch exactly the same size c)Impossibility of incorporating water-soluble salts, such as K nitrate or Ba nitrate, in the balls because these salts would be diffused in water during the manuf. Even some of the insol salts(such as lead stearate) cannot be incorporated in the balls

*Refs:* 1)Fred Olsen,G.C.Tibbitts & E.B.W.Kerone, USP 2047114(1936) 2)F.Olsen & G.C.Tibbitts, USP 2111075(1938) 2a)H.F.Schaefer,USP 2160626 (1939) 3)F.Olsen,G.C.Tibbitts & E.B.W.Kerone,

USP 2175212(1939) 4)Ibid,USP 2206916(1940) 5)Davis(1943),328-30 6)A.Strasser,PATR **1459** (1944)(Astudy of consolidated ball powder from Western Cartridge Co) 6a)C.E.Silk,USP 2375175('45) & CA **39**,3672(1945)(Spherical grains of smokeless proplnt) 7)T.R.Olive,ChemEngrg **53**,No 12,92-6 & 136-9(1946)(Ball-powder process upsets expls industry tradition) 7a)Stettbacher(1948)- not described 8)Riegel, IndChem(1949),718-19 9)P. Tavernier,MP **31**, 208-10(1949)(Density of ball powder) 10)E.P.Reichardt & B.C.Baldridge,USP 2543535(1951) & CA **45**, 5930(1951)(The ballistic prop of ball-type proplnt can be regulated by controlling the amt of w left in the grain prior to rolling) 10a)Belgrano(1952)- not described 10b)Stettbacher,Pólvoras(1952)- not described 11)Anon,Explosivst **1953**,41-42(prepn of ball powder) 12)J.Fauveau & J.Chosson,MP **35**,183-90 (1953)(Surface treatment of ball powder in liquid medium) 12a)G.R.Cox,USP 2715574(1953) & CA **49**,15542(1955)(Prepn of high-d ball powder) 13)Anon,Explosivst **1954**,46 (Ball powder is now manuf by the Poudreries Réunies de Belgique, mainly for use in caliber .30 cartridges adopted for the official NATO rifle, which was developed in Belgium) 14)P.Tavernier,MP **38**,193-232(1956) (Ball powders and rolled ball powders; theory) 15)J.J.O'Neil,Jr & G.R.Cox,USP's 2740704-5 (1956) & CA **50**,9742(1956)(Manuf of ball powder) 16)J.J.O'Neil,Jr Ordn **41**,365-7(1956)(Manuf of ball powder by Olin Mathieson Chemical Corp) 17)W.A.Schmelling,Badger Ordnance Works, TechRept No **176**(1957)(Reclamation of NC and NG from scrap double-base proplnts for use in ball powder manuf) 18)J.H.Herd,Naval Ordnance Lab. NavOrd Rept No **6131**(1958)(Approval of ball powder type WC-860 for use in the explosive actuator MK 4 MOD O) 19)J.J.O'Neil & G.R.Cox, USP 2830886(1958)(A process for the manuf of globular proplnt) 20)R.L.Cook & E.A.Andrew, USP 2888713(1959) & CA **53**,16541(1959)(A continuous process for manuf of globular proplnt) 21)C.M.Reinhardt, USP 2919181(1959)(A process for manuf of globular NC) 22)P.F.Schaffer,formerly of PicArsn; private communication 23)E.F.Stevenson & W.P.Morton,Jr,PicArsn; private communications(1960)

**BALn.** A Fr propellant. See under Ballistites

**Balsa Wood Nitrated.** W.de C. Crater,USP 2174914 (1939) & CA **34**,887(1940) proposed several expls mixts contg nitrated balsa wood of N content 9 to 11.5%, as for instance: nitrated balsa wood, AN, Na nitrate, charcoal & sulfur

**BAm or B(AM)** (Poudre)(Fr). See under B(Poudre)

**Bamboocellulose Nitrates.** B.Rassow & A.Reckeler,Nitrocellulose **3**, 41-45 & 61-64(1932) prepd a product contg ca 11.3%N by nitrating an Indian bamboo for 2hrs at 20° using 30 parts of mixed acid consisting of 19.8% nitric acid, 66.7% sulfuric acid & 16.5% water. A Japanese bamboo gave under the same conditions a product with ca 10.8%N. The yield in both cases was comparable to that of cotton or woodpulp

**Banana Oil.** See Amyl Acetate in vol 1,p A678-L of this Encyclopedia

**Bangalore Grenade**(Granata bangalore in Ital). According to Molina,Esplodenti(1930),374-5, this is a hand grenade using dry guncotton(fulmicotone, in Ital) as a bursting charge

**BANGALORE TORPEDOES; Detonating Cables; Demolition Hoses and Demolition Snakes.** These are long demolition devices which are intended chiefly for clearing mine fields and for blasting passages through wire entanglements. There are also some other uses indicated below

Bangalore torpedoes exist in several modifications. The std US device, *M1A2* which was used successfully during WWII, consists of 10 loading assemblies, 10 connecting sleeves and 1 nose sleeve. The loading assembly consists of a steel tube 5 ft long and 2 1/8" in diam, filled with 7.6lbs of 80/20 amatol (or other solid HE) and topped off by 4" of TNT(ca 1.4 lbs) at each end. Each end is capped and grooved and contains a fuze well to accomodate a detonator, primacord, or a blasting cap(such as Corps of Engineers Cap, called now Cap, Blasting Special, described in Ref 14, or a commercial one not smaller than No 8) attached to any of the std firing devices. Initiation may also be accomplished by a detonator or four turns of primacord wrapped around one end of the tube. The torpedo may be used as a single tube or several tubes(called loading assemblies) may be fastened together by means of connecting sleeves as shown on Fig 222,p 37 in Ref 2 and Fig 192, p 266 in Ref 5. A nose sleeve with a rounded point is provided for ease in pushing the torpedo through obstacles(Refs 2,3 & 5)

A short length of bangalore torpedo can be used as an antitank(A/T) or an antipersonnel (A/P) mine or as a booby trap. It was also used,

according to Ball(Ref 4), by US troops for destruction of pill boxes during the attack on the Siegfried Line in March 16, 1945. For this, a 5-ft length of bangalore torpedo, equipped with a pull fuze, was dropped inside a narrow vent pipe sticking out the top of each Ger pill box. This was the idea of an unknown Amer soldier and the device was fired after the *bazooka shot* and the *pole charge* failed to penetrate completely through the vent

A more recent US bangalore torpedo is the *M1A2*. It is described in conf Ref 6, but in unclassified Ref 12 it is mentioned that its chge is 9.5 lbs of Comp B or Comp A-3. The US Military specification requirements are in Ref 13 *Detonating Cable* can be used for the same purposes as a bangalore torpedo. A std US device *M1* for clearing narrow lanes in A/P mine fields consists of a nylon-covered cable(also called rope),170ft long and ca 1" in diam, which contains 46 lbs of oil-soaked PETN(regular detonating cord should not be used as a substitute). The cable consists of 19 strands of *special detonating cord*, each contg ca 100 grains PETN per ft. One end of the cable(which contains a booster chge and a threaded cap well for inserting a 15-second delay detonator for exploding the cable) is anchored to a stake driven into the ground, while the other end is projected across the mine field by a JATO unit. The cable is then exploded by the detonator at the anchored end(Ref 5,pp 287-8). In the older device, which was used during WWII, the cable(rope) consisted of 13 strands of detonating cord 215ft long. In prepg the cable, the 13 strands(cords) were held by several men and wrapped with twine and tape. One end of the cable was attached to the ground and provided with US Army Special Nonelectric Blasting Cap (described in Ref 14), a 15" length of time fuse and a lighter. The other end of the cable intended to be projected across a mine field was attached by means of manila rope to the body of a 105mm base-ejection smoke shell(M84), modified to function as a rocket. For this, the empty shell with fuze deactivated was placed upside down and, after removing the base-plate, about 1" of earth dirt was temped in the nose of the shell to seal off the hole leading to the fuze. This was followed by ca 150g of propellant wrapped in a cloth and provided with US Army Special Non-electric Cap, described in Ref 14, a 12" length of fuse and a lighter attached at the base of the shell. The remaining space in the shell was filled and lightly tamped with earth containing no gravel or stones. The shell was then placed at an angle of ca 30° in the desired direction and the fuse lighters on both the shell and the cord were pulled out. The shell acting as a rocket was propelled to a distance of ca 200ft while dragging the detonating cord with it. After several seconds the detonating cable exploded. For a more detailed description of this device, see Ref 1, pars 46.04-a to 46.04-i *Demolition Hoses,* used by some European countries, such as Germany and Czechoslovakia, were long flexible hoses made of various materials. One end of such hose was stationary while the other end could be projected to a desired distance across a mine field or other obstacle by means of a rocket, mortar projector or other device. Then a liquid expl, such as *Myrol*, which was used by the Germans(Refs 8 & 10), was pumped into the hose and the explosive detonated by means of a conventional initiating device placed at the stationary end of the hose. The Czechs used a device called *Hadice* which is briefly described in conf Ref 7 *Demolition Snakes*, intended principally to breach minefields, may also be used to breach bands of log posts, steel rails, antitank ditches and some small concrete obstacles. A demolition snake consists of sections made up of two parallel linear charges of expls encased betw corrugated metal plates, bolted together to form an assembly rigid enough to be towed or pushed by a light or medium tank yet flexible enough to pass over uneven ground. Detonation of snakes was accomplished from within a moving or stationary tank by the impact of a .30 cal bullet from a machine gun against a vertical plate forming part of the two impact fuzes, one attached toward the leading end and one at the rear of the charged segments of the snake assembly

The demolition snake *M2*, described in Ref 1, pars 46.02 to 46.03 and in Ref 5,pp 288-9, is the earliest model. It was made of corrugated steel plates. The usual length of this snake was 400ft. The chge consisted of 10 lbs of 80/20 amatol per ft. The first 20ft of the snake and rear 60ft contained no expl. This prevented premature explns while pushing or towing. Gross wt of a 400-ft snake was ca 7 tons. Snake *M2A1* was similar to M2 except that its load was 14 lbs of amatol per ft. Gross wt of a 400-ft snake was ca 8.5 tons. Snake *M3* is the current model. It is described in unclassified Ref 5,p 289. The snake is 14" wide, 5" high and 400 ft long when assembled. Corrugated aluminum plates, 9ft long, fastened with steel bolts, washers and nuts, form the body of

the snake. A pear-shaped aluminum nose, attached to the forward end of the snake in such a way that the nose can swivel slightly, aids in guiding the snake over and around obstructions. Other components and accessories adapt the snake for pulling or pushing by a tank. One hundred twenty-eight demolition charges M2 are used with each M3 snake, 400ft long. Each charge M2 is elliptical in shape and weighs 40lbs including ca 35lbs of expl, which is 80/20 amatol with a booster chge of crystalline TNT at each end. The chges are loaded in 320ft of the 400-ft snake, giving an expl wt of 14 lbs per loaded foot. Dirt-filled tamping bags are placed adjacent to the charges and extending 10ft toward the nose of the snake and 20ft toward the rear to prevent the chges from shifting. Loading assemblies for bangalore torpedoes(see above) may be used as an alternative expl charge. Two fuzes, bullet impact, M1 are supplied with each demolition snake. Total wt of this snake is ca 9 tons including 4.5 tons of expls(Ref 5,p 289)

*Refs*: 1)Anon,WarDept Field Manual FM **5-31** (1944-5),pars 46.02 to 46.05-i 1a)Anon,'Ammunition Inspection Guide', TM **9-1904**(1944), 270-1 2)Ohart(1946),375-6 3)Anon,'Complete Round Charts'**5981**,ORDIM,QCO,Washington DC(1950), sheet 45 4)C.E.Ball, The Town Journal, April 1955,p66 5)Anon,'Ammunition General', TM **9-1900**(1956), 266-7 & 286-9 6)E.J.Murray & S.J. Lowell,PATR **2297**(1956)(Conf)(Development of improved expl chges for Bangalore Torpedoes M1A1 & M1A2 and Demolition Snake M3) 7)'Information Rept of the Central Intelligence Agency', No CS-LT-K-RC-**3831**,4 Dec 1956(conf) 8)PATR **2510**(PB No 161270)(1958),p Ger 115 9)US Specification MIL-T-1339(Ord), Bangalore Torpedo M1A1 10)Dr Hans Walter,PicArsn,Dover,NJ; private communication 11)A.B.Schilling,PicArsn; private communication 12)'Ammunition Complete Round Charts',Book III, Ordnance Ammunition Command,Joliet,Ill,15 Oct 1959, Chart 22 13)US Specification MIL-T-2087 14)US Specification MIL-C-14003A,Cap,Blasting,Special,Nonelectric (Type 1) and Cap,Blasting,Special,Electric(Type 2)(formerly known as Corps of Engineers Caps) (See also this volume under BLASTING CAPS)

**BAR.** Browning Automatic Rifle. See under Browning's Weapons

**Baratol** is an expl compn contg Ba nitrate & TNT in various proportions, developed by the British and used during WWII. It was claimed that Ba nitrate acts not only as a non-hygroscopic and non-corrosive oxidizer and extender for TNT but also as a substance which improves the propagation of the detonation wave of TNT, Baratols are not as efficient expls as amatols(on a wt basis), but on a vol basis there is practically no difference

Originally there were the following two formulations for Baratols:

a) *80/20 Cold Mixed Baratol* (Brit nomenclature), called *20/80 Baratol* by the US nomenclature. It contains 20±2.0% Ba nitrate [freshly ground to pass the BSI(qv) sieve No 60 and dried to a moist content not higher than 0.1%] and 80±2.0% TNT (ground to pass the std BSI sieve No 25). This Baratol has been prepd by blending of ingredients at RT, preferably at the site of the plant where filling of ammo with Baratol takes place. Loading of ammo can be done either by hand stemming or by direct pressing. The prepd Baratol shall all pass No 8 BSI sieve and at least 75% to pass No 25 BSI sieve. Moisture content must not exceed 0.10%. No grit, visible impurities or foreign matter must be present

b)*90/10 Poured Baratol*,(Brit nomenclature), called *10/20 Baratol* by US nomenclature. It contains 10±1.0% Ba nitrate(ground to pass the BSI sieve No 72) and 90±1.0% TNT(Grade 1 or 2). Its prepn is as follows:

A freshly ground Ba nitrate is gradually added while stirring to molten TNT, preheated to 90°, not allowing the temp to drop below 85° during mixing. The mixt is cooled while stirring to the consistency of 'porridge' and poured into suitable molds to be solidified in slabs of ca 1/2" thickness. The slabs are broken into pieces suitable in size for *biscuit(pellet)* loading of ammo. The d of the slabs should be about 1.63 to 1.68. Any pieces showing sponginess are discarded. Another method of loading consists of pouring the 'porridge' into components in one or more increments. Before a 2nd or subsequent pouring is made, the shrinkage cavity from the previous pouring is broken through. Final toppings may be made by pouring the Baratol melt mix directly at 85° without allowing it to cool further in the melt pot. The props of *90/10 Baratol* (British) were reported in Ref 2 as follows: *color*-buff; *density of loading* ca 1.65; *mp* 80-5°; *brisance* (by sand test)-36 g sand crushed, vs 43 g for TNT; (relative brisance 84% TNT); *detonation velocity* - 5900 m/sec at d 1.65, vs 6900 for TNT; *corrosiveness*-non-corrosive; *hygroscopicity*-non-hygroscopic; *impact sensitivity*-12" vs 14" for TNT

on PicArsn App with 2-kg wt; *power*(by Trauzl Test)-98%TNT,(by Ballistic Mortar)-98% TNT; *rifle bullet sensitivity*-20% detonations from .30 cal bullet shot from a distance of 90ft; *stability* (thermal)-as stable as TNT; *uses*-as bursting chge in depth bombs, A/T(antitank) mines and some grenades

As both the above Brit Baratols have highly negative oxygen balance to $CO_2$ (-53.1% for 80/20 and -65.5% for 90/10 Baratol) (the method for calculating OB of a mixt is described under Baronal) two new formulations contg much higher percentages of oxidizer(Ba nitrate) were developed in the US. One contained: Ba nitrate 73 & TNT 27%(OB to $CO_2$ +2.1% and to CO + 15.6%), while the other consisted of Ba nitrate 67 & TNT 33% (OB to $CO_2$ is -4.2% and to CO + 12.1%). The latter compn, called *67/33 Baratol* in US and *33/67 Baratol* in Gt Britain, is still in use and its props are as follows: *booster sensitivity* 100g Tetryl detonates cast Baratol in 50% of trials through 0.32" of wax; *brisance*(by sand test)-26.8g sand crushed vs 48.0g for TNT(relative brisance 56% TNT); *density* (cast) 2.55; *explosion temperature*- ignites at 385° in 5 secs; *Hygroscopicity*- nil at 30° & 90%RH; *impact sensitivity* 35cm vs 90-100cm for TNT(BurMines App, 2kg wt); 11"(sample wt 24mg) vs 14" for TNT (PicArsnApp,2kg wt); *power*—not given in refs listed below; *sensitivity to initiation*—0.40g of Baratol require a detonator contg 0.20g LA & 0.10g Tetryl(Ref 5)

*Preparation of 67/33 Baratol.* The approx wt of Ba nitrate, preheated to ca 90°, is added to molten TNT contained in a melting kettle equipped with an agitator. Mixing is continued until a uniform mass is obtained. Then the melt is cooled slightly while the agitation is continued and is loaded into ammo at the lowest temp at which it will flow freely(Ref 4)

*Analytical Procedure Used at Picatinny Arsenal for Baratol*( as described in CLR 121813). Transfer an accurately weighed sample of ca 2g dry Baratol to a 400ml beaker. Add 200ml of dry benzene and allow the mixt to digest on a water-bath for 1hr. Transfer quantitatively the insol portion to a large tared sintered glass crucible (which has been previously washed with benz and dried at 100±2° for 1hr) and wash its contents with four 25ml portions of benz, aspirating each time until most of the benz is removed. Dry the crucible at 100±2° for 1hr, cool in a desiccator and weigh. The wt of residue is Ba nitrate *Analytical Procedures Used by the British* include detn of moisture content(max allowable 0.25%) and detn of composition. For the moist content, a 5g sample of pulverized material in a shallow dish is kept in vacuo over concd sulfuric acid for 18 hrs and then reweighed. The moisture free material is transferred to a Gooch crucible in which it is extracted with hot, dry benz until free of TNT. The crucible with residue is dried at 100° for 1 hr, cooled in a desiccator and reweighed(Ref 3)

*Refs:* 1)Thorpe **1**(1937),619 & **4**(1940),464 2)All&EnExpls(1946),89-90 and table,p 57 3)US Military Intelligence Division Reports R-979-51 & R-1149-51(1951) 4)PATR **1740**,Rev 1 (1958)

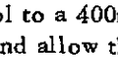
**Barbarit.** A Ger chlorate expl formerly manufd by the Sprengstoff-Fabriken Kriewald bei Gleinitz: K chlorate 90-92 & high boiling petroleum fraction 10-8%. Flash point of petroleum was required to be not below 105° and boiling point not below 242° *Ref:*A.Marshall,'Dictionary of Explosives', Churchill, London(1920),12-13

**Barbe**(no first name or initial given) proposed in 1883 to diminish the sensitivity of NC by incorporating organic or inorganic nitrates, preferrably AN. The same inventor proposed in 1885 to diminish the hygroscopicity of AN and to assure its neutrality by incorporating some Amm carbonate *Ref*: Daniel(1902),56

**Barbette.** A mound of earth or a specially protected platform on which guns are mounted to fire over a parapet; a cylinder of armor on a warship that gives protection to the rotating part of the turret below the gunhouse; a fixed superstructure on an armored vehicle, usually with gun mount of limited traverse

*Refs:* 1)F.W.F.Gleason, ArOrd **31**, 369(1947) 2)Merriam-Webster's (1961) 175

**Barbituric Acid or Malonylurea**



$HN.CO.NH.CO.CH_2.CO$; mw 128.09, N 21.87%; wh crysts, mp 245°. Its mono-Na salt was proposed as a component of composite AN propellants(see under Combustion Catalysts for Composite Proplnts)

*Ref*: Beil **24**,467,(410) & [267]

**BARC.** See under Amphibian Vehicles, in Vol 1, p A678-L of this Encyclopedia and the article of H.A.Jacobs in Ordnance **38**,529-31(1953)

**Barisutaito.** Jap for Ballistite

**Barium**,Ba, at wt 137.36; silvery metal, d 3.5mp 850°, bp 1140°; attacked by w and by alc. Can be prepd either by electrolysis of fused salt(such as Ba chloride) or by the reduction in an evacuated retort of a Ba compd(such as oxide) with Al at 1200° or higher. Used in many alloys. Lenze & Metz(Ref 2) investigated explns produced on heating mixts of metallic Ba with organic halogen compds, such as tetrabromomethane, tetrachloroethane, etc. They also detd the sensitivity to impact, Trauzl test values and some other props of such mixts

*Refs*: 1)Mellor **3**(1923),620-49 2)F.Lenze & L. Metz,SS **27**,257-8,294 & 337-8(1932); CA **27**,844 (1933) 3)Gmelin,Syst Nr **30**,Hauptband(1932),1-7 and Ergänzungsband(1960),1-272 4)Thorpe **1**(1937), 631 5)Kirk & Othmer **1**(1947),462(under Alkaline Earth Metals) 6)Giua, Dizionario **1**(1948),625-6 7)Ullman **4**(1953),171-2

**Barium Acetylide.** See Vol 1,p A70-R of this Encyclopedia

**Barium Azide.** See Barium Diazide in Vol 1 p A523-L

**Barium Bichromate.** Same as Barium Dichromate

**Barium Boride.** See under Borides

**Barium Bromate.** See under Bromates

**Barium Bromide.** See under Bromides

**Barium Carbide.** See Barium Acetylide, Vol 1, p A70-R

**Barium Carbonate.** See under Carbonates

**Barium Chlorate.** See under Chlorates

**Barium Chloride.** See under Chlorides

**Barium Chromate.** See under Chromates and Dichromates

**Barium Diazide.** See Vol 1,p A523-L

**Barium Dichromate.** See under Chromates and Dichromates. Several pyrotechnic compns contg $BaCrO_4$ are described by H.Ellern,'Modern Pyrotechnics',Chem Publg Co,NY(1961),283-4

**Barium Fluoride.** See under Fleorides

**Barium Hexanitride.** Same as Barium Diazide

**Barium Hydride.** See under Hydrides

**Barium Hydroxide.** See under Hydroxides

**Barium Hypochlorite.** See under Hypochlorites

**Barium Hyposulfite.** Same as Barium Thiosulfate

**Barium Iodate.** See under Iodates

**Barium Iodide.** See under Iodides

**Barium Nitrate**(BaN)(Nitrobarite)(Barytsalpeter, in Ger), $Ba(NO_3)_2$, mw 261.38, OB to BaO & N +30.6%. Col cubical & octahedral crysts, d 3.244 at 23°, mp 592°, bp dec;$n_D$ 1.572; sol in w(5.02g in 100g w at 0° and 34.2g at 100°); sl sol in acids; insol in alc & in eth. Can be prepd either by treating native carbonate(witherite) or the sulfite with hot dil nitric acid, followed by crystn; or by double decompn of $BaCl_2$ with Na nitrate(such as Chile saltpeter) in hot aq soln with subsequent pptn of BaN

When heated above 800° BaN decomp into BaO, N & O. It has been used as an oxidizing agent in composite expls, proplnts, & pyrotechnics as, for instance, in Baratol, Baronal, Brugere(Poudre), Tonite, detonators, fuzes, primers, etc. One of the Jap expls used during WWII in boosters for demolition charges contained: BaN 34.5, $NH_4ClO_4$ 51.5, oil & trinitronaphthalene 8.2, woodpulp 5.0 & other ingredients 0.8%(Ref 5,p 32). A Rus thermite-type incendiary compn, press-loaded in 76mm shell s, contained BaN 44,K nitrate 6, $Fe_3O_4$ 21, Al 13, Mg 12 & binder 4%(Ref 10,p210). Mixts contg BaN are slower burning than those contg K nitrate and the ignition points are higher. The advantage of BaN over AN is its non-hygroscopicity

Since BaN has the property of emitting green light when heated, it has been used in signal flares, signal rockets, stars, railroad torches, tracer compns and some compns producing white light

Following are some examples: a)BaN 60,K perchlorate 18, Na oxalate 9, shellac 9 & sulfur 4%; used in signal torches(Ref 8,p205) b)BaN 50, K chlorate 35 & shellac 15%; used in green stars (Ref 8,p211) c)BaN 39, K chlorate 39, charcoal 13, shellac 6 & gum arabic 3%; used in green stars(Ref 8,p211) d)BaN 53, K chlorate 31, sulfur 10 & charcoal 6%; used in green signals(Ref 8,

p211) e)BaN 74-80 & Al 36-20; used in tracers (Ref 8,p220) f)BaN 57, Al 30, Sb trisulfide 6, cryolite 6 & castor oil 1%; used in Fr signal cartridges, type Very (Ref 8,p226) h)BaN 55, Mg 35 & binder 10%;used in white tracers(Ref 10,p181) i)BaN 52, Mg 40, K oxalate 6 & binder 2%; used in white tracers(Ref 10,p 181) j)Various pyrotechnic compns listed by Ellern(Ref 13)

US Military requirements for BaN are given in Ref 11, Russian specification requirements are listed in Ref 10,p 29. Detn of Ba nitrate in propInts is described in Ref 12

*Refs:* 1)Mellor **3**(1923),849-64 2)C.A.Taylor & W.M.Rinkenbach, 'Explosives', USBurMinesBull **219**(1923),21-25 3)Gmelin,System Nr **30**,Hauptband(1932),149-64 & Ergänzungsband(1960),305-16 4)Thorpe **1**(1937),639 & **4**(1940),464 5)Anon, 'Handbook of Japanese Explosive Ordnance', Op Nav **30-3M** GovtPrtgOff,Washington,DC(1945),32 6)Kirk & Othmer **2**(1948),315 7)Giua,Dizionario **1**(1948),628-9 8)Izzo,Pirotecnia(1950),205ff 9)Ullmann **4**(1953),178 10)Shidlovskii Pyrotechnics(1954),22,27,29,149,181 & 210 11)US Military Specification MIL-B-162B 12)Military Standard MIL-STD-286A(1956) Method 304.1.2 13)H.Ellern, 'Modern Pyrotechnics', ChemPublgCo,NY(1961), 272-8, 284

**Barium Nitrate Mixtures, Analysis.** See Vol 1,p A586 of this Encyclopedia

**Barium Nitride, Hexa.** Same as Barium Diazide

**Barium Nitrite.** See under Nitrites

**Barium Nitrominoguanidine.** See Nitroaminoguanidine(NAGu) Salts, under Aminoquanidine in Vol 1, p 212-L of this Encyclopedia

**Barium, Organic Salts of.** See under individual organic compds

**Barium Oxalate.** See under Oxalates

**Barium Oxide.** See under Oxides

**Barium Perchlorate.** See under Perchlorates

**Barium Permanganate.** See under Permanganates

**Barium Peroxide.** See under Peroxides. A white tracer compn contg $BaO_2$ is listed by H.Ellern, 'Modern Pyrotechnics', ChemPublgCo,NY(1961), 276

**Barium Picramate.** See Vol 1,p242-L of this Encyclopedia

**Barium Picrate.** See under Picrates

**Barium Resinate.** See under Resinates

**Barium Stearate.** See under Stearates. Its use in smoke-producing compns was patented by J. DeMent, USP 2995526(1961),p6

**Barium Sulfate.** See under Sulfates. A white flare compn contg $BaSO_4$ is listed by H.Ellern, 'Modern Pyrotechnics', ChemPublgCo,NY(1961),274

**Barium Sulfide.** See under Sulfides

**Barium Superoxide.** Same as Barium Peroxide

**Barium Tetrazidocuprate,** $Ba[Cu(N_3)_4]$, a complex salt exploding at 208-9° is described by M.Straumanis & A.Cirulis, Z Anorg Chem **252**,9-23(1943) & CA **38**,3564(1944)

**Barium Thiosulfate.** See under Thiosulfates

**Barlow Bomb.** According to John M.King, formerly of PicArsn, Barlow proposed ca 1936 a mixt of liquid oxygen with a fuel(such as charcoal) as a bursting chge for bombs. This expl mixt was tested sometime before WW11 at Aberdeen Proving Ground and was found to be not as effective as TNT

**Barnwell & Rollason**(no initials given) patented in 1860, in England, modified black powders in which part of the charcoal was substituted with NC. Such powders could be prepd by mixing K nitrate, sulfur & charcoal with soln of collodion cotton in ether & alcohol and then evapg the solvent

*Ref:* Daniel( 1902),57

**Barometric Fuze.** See under Fuzes.

**Baron & Cauvet Explosives.** See Cauvet & Baron Explosives

**Baronal.** A composite expl: Ba nitrate 50, TNT 35 & Al 15%, developed in the US during WWII as a castable filler for underwater munitions(Ref 1). It was hoped that Baronal would be much less sensitive than the British *Torpex-2*(42/40/18 RDX/TNT/Al) but this proved not to be true and, as Torpex-2 was more powerful, it was adopted

as an underwater charge(Refs 1 & 2)

Baronal can be prepd by heating TNT to ca 90° and adding, while stirring, preheated pulverized BaN & Al powder. Following are the props of Baronal: OB to $CO_2$,$H_2O$,BaO & $Al_2O_3$ -23.9%; OB to CO,$H_2O$, BaO & $Al_2O_3$ -6.7%(see note below); *booster sensitivity* 100g Tetryl detonates cast Baronal in 50% of trials through 0.86" of wax; *brisance*(by Sand Test) 39.8g sand crushed vs 48g for TNT; *density*(cast) 2.27-2.32; *detonation rate* 5450 m/sec at d 2.32 & chge diam 1"; *explosion temperature* 345° (ignition in 5 secs); *heat of combustion*($Q_c$) 2099 cal/g; *heat of explosion*($Q_e$) 1135 cal/g; *heat of formation*($Q_f$) 410 cal/g; *hygroscopicity* nil; *impact sensitivity* 30cm(BurMinesApp, 2kg wt) vs 95-100cm for TNT and 12"(sample wt 22mg)(PicArsnApp, 2kg wt) vs 14" for TNT; *power*(by Ballistic Mortar Test) ca 90% of TNT; *sensitivity to initiation* 0.40g of Baronal requires a detonator contg 0.20g L A & 0.10g Tetryl

Principal use of Baronal is for filling bombs, but it also can be used as replacement for Alumatol, Ammonal, etc

*Note:* In Vol 1,p A515 of this Encyclopedia is described a method for calcn of oxygen balance for individual compds, but nothing is said about calcn of OB's for mixtures. The simplest method is to proceed as follows: a)Calculate OB's of individual components and divide the values by 100 b)Multiply each OB by the corresponding percentage in the mixture and then add the resulting values

Taking Baronal as an example, we have OB for BaN to BaO = +30.6%, for TNT to $CO_2$ & $H_2O$ = -73.9% and for Al to $Al_2O_3$ = -88.9%. This gives for 50/35/15 -Baronal: 50× 0.306 + 35×(-0.739) + 15×(-0.889) = -23.8%. If TNT goes to CO & $H_2O$, its OB is -24.7%, which will give OB for Baronal: 50 × 0.306 + 35×(-0.247) + 15× (-0.889) = -6.7%

*Analytical Procedure for Baronal.* Transfer an accurately weighed portion of ca 2g to a 400-ml beaker. Add 200ml of dry benzene and allow the mixt to digest on a water bath for 1 hr. Transfer quantitatively the insol residue to a large tared sintered glass crucible (which has been previously washed with benz and dried at 100±2°) and wash the contents with four 25ml portions of benz aspirating each time until benz is removed. Dry for 1hr at 100±2°, cool in a desiccator and weigh. The loss in wt is equal to TNT. Rinse the residue(BaN+Al) with hot distld w until all BaN is removed, dry the crucible with residue(Al) at 100±2° for 1hr, cool in a desiccator and reweigh. The loss in wt is equal to BaN, while the residue is equal to Al(Ref 6)

*Ref:* 1)D.P.MacDougall, OSRD **1035**(1942) 2)NDRC, Summary Technical Rept of Div 8, Vol 1 (1946),33 3)Allied & EnExpls(1946),85 4)W.G. Penney et al, ProcRoySoc **A204**, 14(1950)(Detonation rate of Baronal) 5)PATR **1740**,Rev 1 (1958) 6)C.Ribaudo,PicArsn;private communication(1960

**Barrage, Balloon.** See Balloon, Barrage

**Barrel, Erosion of.** See Erosion of Gun Barrel

**Barrel Finishing** is described in the "Handbook of Barrel Finishing", by R.Enyedy,Reinhold,NY (1955)

**Barrel, Gun (or Tube).** The cylindrical metallic part of a gun which controls the initial direction of the projectile. The term *tube* is preferred for designating the larger diam barrels(See also Bore)

*Ref:* Glossary of Ord(1959),32

**Barrel (or Bore)Oscillations (or Vibrations)** (Laufschwingungen in Ger). In the course of firing a projectile, the gun barrel does not remain stationary but oscillates somewhat, being especially pronounced at the muzzle-end of the barrel

C.Cranz & K.R.Koch designed, in 1896, an apparatus which permits registering by high-speed photography, the vertical as well as the horizontal oscillations of a gun barrel. The same apparatus takes pictures of the projectile as it leaves the muzzle

*Ref:* Cranz **3** (1927), 279-281

**Barrel, Rocket.** A vernacular term for the major component of a liquid-propellant rocket motor wherein combustion takes place; the term *thrust-chamber assembly* is preferred

*Ref:* Rocket Encycl(1959),40

**Barricades in Explosives and Ammunition Installations.** Barricades are required for protection of inhabited buildings, factories, magazines, railroads, highways, bridges, etc from explosions in installations in which expls or ammunitions are manufd, handled or stored. A barricade can be either *natural*(such as a hill or timber of sufficient density) or *artificial*(such as a sand- or earth-filled embankment with a min width of 3ft

at the top). It should be located at a min of 4ft from the bldg it is to screen and either one or both sides of the barricade may be supported by concrete, timber or masonary walls. A bldg is considered to be *barricaded*(or screened) if the heights of barricades are such that a straight line drawn from the top of any sidewall of the bldg contg hazard to the eave line of any other bldg or to a point 12ft above the center of a railroad, highway, etc, will pass through the intervening barricade (Refs 1 & 8)

The permitted distances from barricaded bldgs (called *barricaded distances)* to other bldgs, railroads, etc are enumerated in the "American Table of Distances for Storage of Explosives", as Revised and Approved by the Institute of Makers of Explosives, Sept 30, 1955. This table is given in Refs 14,15 & 16. Distances shown in this table should be doubled if dangerous bldgs are not barricaded

Igloos, when protected by a barricade at the door end, are considered to be barricaded in all directions and *barricaded distances* may be used as minimum safe distances in locating them from other magazines, operating or inhabited bldgs, railroads, etc. Where igloos are not barricaded at the door end, the distances in regard to the bldgs located within the area bounded by lines drawn from the door of the igloo and inclined by 30° from a line drawn perpendicular to the front of the igloo should be double those given in the table of Refs 14,15 & 16. Such distances are called *unbarricaded distances*

The work on standardization of barricade design and on testing of various types of barricades conducted at PicArsn by Industrial Division is described in Refs 3-7,10-13 & 17

*Refs:* 1)Anon, "Ammunition Inspection Guide", TM **9-1904**(1944),799-801 2)C.Field et al,"Barricades",Naval Prooving Ground,Arco,Idaho(1945) 3)B.Kroll & A.Kush,PicArsnIndDivTechReptPED **501-1**(1953)(Standardization of barricade design) 4)Ibid,PED-**501-2**(1953) 5)R.Flohr & A.Kush, Ibid,PED-**501-3**(1954) 6)A.Kush,Ibid,PED-**501-4** (1955) 7)S.Wisneski,Ibid,PED-**501-6**(1955)(Effectiveness of safety glass as shield barricade material) 8)Anon, "Military Explosives", TM **9-1910**(1955),303-4 9)Anon, "Care,Handling,Preservation and Destruction of Ammunition", TM **9-1903**(1956),35-7 10)S.Wisneski & A.Kush,Pic ArsnIndDivTechRept PD-**501-7**(1957)(Relative effectiveness of barricade window material and support area) 11)A.Kush,Ibid,PD-**501-9**(1957) (Standardization of barridade design) 12)A.Kush Ibid,DB-TR: **5-57**(1957)(Evaluation of vented barricade DP-54711 utilized in handling of explosive powders) 13)A.Kush,Ibid,DB-TR:**11-57** (1957)(Testing of flue-vented barricade DP-44206 14)SAX(1957),154-5 15)Anon,"Ordnance Safety Manual", ORDM **7-224**,,Secn 17(1958) 16)Cook (1958),354-5 17)B.Kroll et al,PicArsnIndDiv TechRept DB-TR: **5-58**(1958)(Barricades)

**Barrier Creams** are used in expls and ammo plants for protecting the human skin from airborne expls or toxic materials. According to Cumming et al (Ref), a satisfactory barrier cream should have a softening point of ca 22° to facilitate spreading in the layer of ca 20$\mu$ thickness to avoid penetration by airborne tetryl crystals of ca 5$\mu$ in size. The so-called *Cambraild Barrier* contg paraffin wax(mp 135°F) 20, vaselin 40, lanette wax(as emulsifying agent) 10 & water 30% is considered satisfactory because when applied to the skin it protects it for ca 6hrs from airborne TNT or Tetryl particles. Incorporation of 2% boric acid and other solids impairs the efficiency of the above barrier. Lanolin and most vegetable oils and greases are considered unsuitable as barriers because many expls (TNT,PA,RDX,etc) dissolve in them

*Ref:* W.M.Cumming et al, BritJIndMed **4**,237-41 (1947) & CA **42**,2429(1948)

**Barrier Materials** may be defined as substances designed to withstand, to a specified degree, penetration of water(liq or vapor), certain gases (as desired), oils & greases. Barrier materials may serve to exclude or retain such elements without or within a package. These materials (especially the flexible types) are used now extensively in all types of military packaging

There are four major types of barrier materials used now in the US for military purposes: a)Waterproof b)Greaseproof c)Water-vapor-proof and d) Combinations of a,b & c. Almost all the barrier materials in use today are composed of several layers or plies. The plies are usually cemented together with suitable adhesives(*laminants)* to form a *laminated structure*, although several other methods of making multi-ply sheets are also used. Materials used for making plies include: kraft paper, cotton scrim, aluminum foil, polyethylene, cellulose acetate, Mylar, etc

A description of flexible barrier materials used in military packaging is given in the lecture of Weiner(Ref 1)

US military requirements and tests for barrier materials are covered by several specifications

which are listed in Ref 3, of which the Specs MIL-B-121B and MIL-B-13239B are the most frequently used by the Army

MIL-B-121B covers flexible,greaseproof,waterproof barrier material for the protection of military supplies and equipment during transportation and storage under all climatic conditions, while MIL-B-13239B covers flexible, waterproof, all temperatures barrier materials of several types, such as bailing, case liners & wrappers, interior wrapping, materials for interior packaging bags, and temporary tarpaulins

MIL-B-3959 covers barrier materials for moderately water-vaporproof interior packaging bags. It is also used by the Army

Spec MIL-B-131C, covering barrier materials, water-vaporproof, flexible, is used mostly by the US Navy

*Refs:* 1)H.M.Weiner,"Flexible Barrier Materials in Military Packaging", A lecture delivered at PicArsn in March 1954 2)Packaging Institute, Inc,"Glossary of Packaging Terms",NY(1955),31-2 2a)R.H.Devore,"Long-Term Storage Tests of Barrier Materials",PATR **2121**(1955) (Conf) 3)"Index of Specifications and Standards(Used by Department of the Army",vol**2**(1959),14 4)G.R. Rugger & Betty Garnis, PicArsn;private communication(1960)

**Baryte.** Fr for Barium Nitrate

**Baryte**(Dynamites). Under the title, Dynamites à la baryte, Daniel(1902),57, describes the following dynamites proposed by A.Nobel: **No1**:BaN 65.21, NG 21.74 & charcoal 13.05% **No2**:BaN 70.0, NG 20.0 & resin 10.0%

**Baryte**(Poudre) was, according to Daniel(1902), 57, a mixt of BkPdr 80 & Ba nitrate 20%. It was used in Germany ca 1865 in large caliber guns

**BAS.** A cast double-base proplnt developed at ABL. Its compn & props are in conf "Propellant Manual"SPIA/M2(1959),Unit No 456

**Base.** See under Acid and Base,Vol 1,p 87-R of this Encyclopedia

**Base Charge of a Detonator.** See under Detonators

**Base Charge of a Propellant.** When a proplnt chge is loaded in bags(as in separate-loading and some semifixed ammo), it is usually devided into a number of bags corresponding to the zones of fire. The principal charge(usually the largest), which corresponds to zone 1, is called the *base charge* and is inserted closest to the primer. Additional charges are called *increments*. For the longest desirable range the charge consists of a base chge and all the increments and if shorter ranges are desired, one or several increments are removed from the gun prior to firing

*Refs:* 1)Hayes(1932),32-3 2)Ohart(1946), 181, 184 & 192 3)Anon,"Ammunition General", TM 9-1900(1956),130-1

**Base Cover**(also called Base Plate). Since the material used for the manuf of shell bodies(cast steel and sometimes cast iron) can be in some cases porous, there is a possibility that the hot gases of propellant chges in artillery weapons might penetrate through the bottom and either ignite or detonate the contents of the shell, which can be either chemical or HE. In order to prevent direct contact of hot gases with the bottom of the shell, the following methods have been used: a)For weapons of ca 75mm to ca 155mm, the base is protected by a steel disc soldered or welded to the base or by a sheet brass disc brazed to the base(Refs 1 & 2 and Ref 3,pp 5,9,12,13 & 220) b)For larger caliber weapons(such as 155mm add up), the base cover assembly consists of a shallow copper cup placed over a lead disc. The cup is held in a dove-tailed groove in the base of the projectile by means of a strip of lead calking wire which is hammered down to fill the groove completely and to bend the flange of the copper cup. This type of cover is called *calked type base cover*(Ref 1,p 559; Ref 2,p 110 & Ref 3,pp 29 & 212)

*Note:* As the metal in current cast steel or cold extrusion shells is less porous than heretofore, there is a tendency to eliminate base covers, especially in smaller caliber shells(Ref 4)

(See also Base Plate)

*Refs:* 1)Hayes(1938),554, 559, 562 & 564 2)Ohart (1946),98-9 & 110 3)Anon, "Artillery Ammunition", TM **9-1901**(1950), 5, 9, 12, 13, 29, 212 & 220 4)A.B.Schilling,PicArsn;private communication (1960)

**Base Detonating Fuze.** See under Fuzes

**Base Ejection Smoke Shell.** See under Smoke Shells

**Base Ignition Smoke Shell.** See under Smoke Shells

**Base of a Projectile** is the part of the projectile aft of the rotating band
*Refs*: 1)Hayes(1938),559 2)Anon, "Artillery Ammunition", TM **9-1901**(1950),8

**Base Plate** usually refers to a thick metallic threaded disc which serves to close the rear conical section of a bomb after loading(Ref 1). The same disc is called *body plug* in Ref 2
*Refs:* 1)Ohart(1946),217 2)Anon, "Bombs for Aircraft", TM **9-1980**(1950),35

**Base Plug** usually refers to a thick threaded metallic disc used for closing the base section of a shell after loading it from the rear(compare with Base Plate and with Base Cover)
*Refs:* 1)Ohart(1946),106 2)Anon, "Artillery Ammunition", TM **9-1901**(1950),9,12 & 13

**Bases Used in the Manufacture of Explosives and Propellants.** Following are a few examples of bases used in expl plants and labs: a)Ca hydroxide has been used as a catalyzer in some reactions and as neutralizer of acidic wastes from plants manufg acids, TNT, etc b)Ammonium hydroxide- as a neutralizer of acidic materials and as a purifier of crude TNT(such as was practiced during WWII at the West Virginia Ordnance Works). Its use in chem labs is very extensive c)Na hydroxide has been used in some plants for neutralizing acidic substances. For instance, *red waters*(qv) of TNT plants are neutralized and made alkaline prior to their concn in stills. Lab uses include titrations of acids manufd at the plants d)K hydroxide has been used in labs of plants for colorimetric testing of TNT and DNT, etc

**Bashforth Chronograph.** See under Chronographs

**Basic Cupric Azide.** See Cupric Azide, Basic Vol 1,p A533-L, under Azides

**Basic Lead Acetate.** See Vol 1,p A28-R, under Acetates

**Basic Lead Azide.** See Lead Azide, Basic, Vol 1,p A555-R

**Basic Lead Salts of Various Organic Nitrogen Containing Compounds.** Friederich(Ref 1) patented the use as components of primary compns the basic lead salts of picric acid, trinitrocresol, hexanitrodiphenylamine, di- & tri- nitroresorcinol, trinitroörsinol, di- & tri- nitrobenzoic acids, trinitrophloroglucinol, tetranitrophenol, nitrated aminpphenols, dinitronitrosobenzene, polynitronaphthols and mono- & tri- nitromethane. Rathsburg & Friederich(Ref 2) patented the use in detonators of basic mixed lead salts prepd by treating a sol salt of tetrazole or its derivs with a soln of a sol salt of one of the above mentioned compds(such as picric acid), followed by running the mixts into a hot soln of Pb acetate
*Refs:* 1)W.Friederich,BritP 192830(1921) & JSCI **42**,332A(1923) 2)H.Rathsburg & W.Friederich, BritP 195344(1922) & JSCI **42**,804A(1923)

**Basic Lead Styphnate.** See under Resorcinic Acid, Trinitro

**Basic Lead Styphnate, Mixtures, Analysis.** See Vol 1,p A586

**Basic Measurements.** Under this term are included the measurements of length, mass, surface, volume, time, etc
*Ref*: J.Reilly & W.N.Rae, "Physico-Chemical Methods", Van Nostrand,NY,vol(1943),11-73

**Bass.** See Bast or Bass

**Basso Esplosivo**(Ital). Low explosive(propellant)

**Bast or Bass** is the fibrous inner bark of linden, lime and some milkweed trees. It is used for ropes, mats, peasant shoes(such as Rus"lapti"). The term *blast fiber* is applied to fibers obtained from the inner bark of flax, hemp, jute, ramie, etc. They contain a considerable amt of cellulose and can be nitrated to NC. However, these substances are more valuable as fabric materials than as sources of NC. Ramie has been used in France for prepn of pure NC
*Ref*: J.T.Marsh & F.C.Wood, "An Introduction to the Chemistry of Cellulose",Chapman & Hall, London(1945),1,3 & 12

**BAT.** A cast double-base propInt developed at ABL. Its compn & props are given in conf "Propellant Manual"SPIA/M2(1959),Unit No 457

**Batteries, Electric, Dry** are described in Kirk & Othmer **2**(1948),324-340(7refs)

**Batteries, Electric, Storage.** See Accumulators in Vol 1,p A12-L of this Encyclopedia

**Bautzen**(Poudre) consisted of nitrolignin 50 & K nitrate 50%
*Ref*: Daniel(1902),58

**Bautzener Sicherheitspulver.** A Ger coal-mine expl contg not less than 70% AN, not more than 15% TNT, the rest being Ba nitrate
*Ref*: A.Marshall, "Dictionary of Explosives", Churchill,London(1920),13

**Bavarit.** A Ger coal-mine expl: AN 90% together with nitrated naphthalene; charcoal may be added
*Ref*: Marshall, Dictionary(1920), 13

**Bayberry, Wax, Synthetic.** See under Waxes

**Bayen's Fulminating Mixture,** invented ca 1779, consisted of 1 part pptd yellow mercury oxide and 4-5 parts of sulfur. It exploded with violence when struck with a heavy hammer or when heated on an iron plate
*Ref*: Davis(1943),402

**Bayon**(Poudre), patented in France in 1881, consisted of K chlorate, coarse bran & gum arabic
*Refs*: Cundill(1889) in MP **5**,291-2(1892) 2)Daniel (1902),58

**Bayonet.** A steel, thrusting dagger or knife-type weapon designed to be attached to the muzzle end of a rifle, shotgun or musket. The term is probably derived from a short dagger "bayonnette" used in Bayonne, France towards the end of the 15th century
*Refs*: 1)C.J.Foulkes & E.C.Hopkinson "Sword, Lance and Bayonet",Macmillan,NY(1938) 2)Anon,"Small Arms Matériel and Associated Equipment", TM **9-2200**(1949),66-7 3)Encycl Britannica **3**(1952),242-3

**Bazooka,** also known as *Rocket, Antitank, 2.36-inch,M6* and *Launcher, Rocket, Antitank,M1* was designed in the US in the summer of 1942 as a one-man, shoulder-operated weapon, firing rockets

The original bazooka consisted of a one-piece, elec battery-operated weapon, of the open(at both ends) tube type which fired a rocket with a shaped charge warhead. The launcher was provided with sights and shoulder frame. The improved launcher was made in two pieces, weighed 16lbs and was fired by a magneto arrangement. Its rocket(22" long and weighing 6.2 lbs) carried a propellant chge; such as BBP(qv) of 0.4 lb(center-drilled wafers on a central rod) and a shaped charge warhead of 1 lb of Pentolite. Its muzzle velocity was 540 ft/sec and the range 1000yds

The bazooka proved to be very effective against tanks and pill boxes. It also can be used in combination with chemical and smoke rockets for laying down smoke screens at short range(Refs 1,2 & 3)

The current launchers, which can be fired from the shoulder or from a bipod and rear supports, are designed for 3.5-inch rockets. There are several models of such launchers and rockets and their descriptions are given in Ref 4
*Refs*: 1)L.A.Skinner,ArmyOrdn **27**,260-63(1944) 2)Anon, ArmyOrdn **29**,75-7(1945) 3)Ohart(1946), 342-3 4)Anon,"Rockets", TM **9-1950**(1958),33-47

**BBC.** A cast double-base proplnt developed at ABL. Its compn & props are given in conf "Propellant Manual",SPIA/M2(1959), Unit No 458

**BBP or M7**(Propellant). NC(13.1-13.35%N) 54.6, NG 35.5, K chlorate 7.8, carbon black 1.2 & Et centr 0.9%; d 1.68, I(impulse) 130 sec, n (pressure exponent) ca 0.7 & temp coef 0.010. Used in 2.36- & 3.5-inch rockets
*Refs*: 1)"Summary Technical Rept of Div 8, NDRC", Vol 1(1946),101 2)Purchase description PA-PD-46(1951) 3)Armament Engineering(1954), 43(table)

**BBV.** A cast double-base proplnt developed at ABL. Its compn and props are given in conf "Propellant Manual" SPIA/M2(1959), Unit No 493

**BC**(Poudre). See under B(Poudre)

**BCNL**(Poudre). See under B(Poudre)

**BCP Powder.** According to Daniel(1902),58, it was one of the older Brit proplnts, based on nitrate. No compn is given

**BD**(Poudre). See under B(Poudre)

**BDI & BDT.** Cast double-base proplnts developed at ABL. Their compns and props are given in conf "Propellant Manual" SPIA/M2(1959), Unit Nos 495 & 496

**Beaded Powder** is the translation given in CA

(Ref 1) of the Fr term *poudre en perles*. It seems to be the same as *ball powder*(qv), also called *spherical powder* (poudre sphérique, in Fr)(Ref2)
*Refs*: 1)J.Fauveau & R.Delpy,MP **35**,161(1949) & CA **46**,11686(1952) (A new process for coating "beaded" powders in order to improve their progressivity) 2)J.Fauveau & J.Chausson,MP**35**, 175(1953) & CA **49**,12832(1955) (Superficial treatment of spherical proplnt in liquid media)

**Beam-Rider Guidance Systems for Missiles** are described by A.S.Locke,"Guidance", VanNostrand NY(1955),574-83

**Beano.** Designation of a spherical hand grenade
*Ref*:NDRC Summary Rpt,Div 8, Vol **1**(1940),153

**Beating or Pulping**(Pilage, in Fr) of **Nitrocellulose** See under Cellulose, Nitro, Manufacture

**Bebie, Jules**(1877-1956). A professor of Chem Engrg at Washington Univ, St Louis, Mo and author of the book "Manual of Explosives, Military Pyrotechnics, Chemical Warfare Agents" and of several papers on prepn of expls and NC. Born in Switzerland, he studied in Germany under G. Lunge. Collaborated with E.Berl & G.Lunge
*Ref*: 1)J.Bebie; private communication 2)Anon, ChemEngrgNews **34**,3364(1956)

**Becco Chemical Div, Food Machinery & Chemical Corp**, Buffalo 7,NY, manufacturers of hydrogen peroxide, peracetic acid, urea peroxide and several other peroxides as well as sodium perborate and other chemicals used in proplnts & expls
*Ref*: Thomas Register of American Manufacturers, NY,vol 4(1960),98

**Becker, Karl**(1879-1940). Artillery General, one of the outstanding German ballisticians. The Peenemünde Research Center, where V-1, V-2 and many other missiles were developed, was constructed under his guidance in 1937-8
*Refs*: 1)K.Justrow,SS **35**,1-2(1940) 2)Oberst Karl, SS **35**121-3(1940) (Obituary and short biography) 3)L.H.Thomas,JChemPhys **12**,449-53( 1944) & CA **39**,621(1945) (Note on Becker's theory of the shock front) 4)F.Ross,Jr, "Guided Missiles: Rockets and Torpedoes", Lothrop,NY(1951),22

**Beehive Demolition Charge.** See under Demolition Charges

**Beehive Projectile.** See under *Projectiles*

**Beeswax or "B"Wax.** See under Waxes

**Beet Pulp Dynamite.** A gelatin dynamite contg dried beet pulp, was patented in 1928 by C.D.Pratt, USP 1658816 & CA **22**,1477(1928)

**Behavior Towards Heat Tests.** See *Sensitivity to Heat, Flame, etc*; Vol **1**,p XXII

**Beilstein, Friedrich K.** (1838-1906), known for the monumental work "Handbuch der Organischen Chemie", contg info on nearly all known organic compds. Publication was initiated in 1881 as one volume. Since that time, it has grown to nearly 100 books as a collective work. Beilstein was born in Russia of German parentage and became professor of chemistry in 1866(when he was only 28 years of age) at the St Petersburg Institute of Technology, succeeding D.I.Mendeléev. He retired after 30 years and went to Germany to devote his time to writing the "Handbuch". Three editions came out during his lifetime. He was also the author of 88 scientific papers, mostly in the field of organic chemistry
*Refs*: 1)O.N.Witt,JCS **99**,1646-9(1911) 2)E.J. Moore & W.T.Hall, "A History of Chemistry", McGraw-Hill,NY(1939),309-10

**BEJ.** A cast double-base proplnt developed at ABL. Its prepn & props are given in conf Propellant Manual SPIA/M2(1959),Unit No 514

**Beken Mixer,** manufd by the Bramley Machinery Corp,Edgewater,NJ. It is a batch-type mixer unique primarily in the design and action of its two mixing paddles

A pilot scale evaluation of a 15-gallon Beken Duplex Mixer for propellant manuf, conducted at PicArsn, indicated that it can be successfully substituted for other mixers, such as a *sigma blade mixer*
*Ref*: K.H.Russell,"Evaluation of Beken Mixer for Propellant Manufacture", TechReptDB-TR: **7-59**,Industrial Engineering Division, Picatinny Arsenal,Dover,NJ,May 1959

**Belaya Smes'** (White Composition). A Rus percussion compn: MF 80-85 & K chlorate 20-15%
*Ref*: Shilling (1946), 97-8

**Belgian Ammonium Nitrate Gelatin Dynamites.** See Vol 1,p A368(table)

**Belgian Control Tests for Explosives.** Under the title "Essai de Contrôle des Explosifs", Dr. L. Deffet described in "Chimie et Industrie", Special Number (1950),pp 445-9, devoted to the 21st International Congress of Industrial Chemistry at Bruxelles(1948), the tests used in Belgium. These tests include the safety tests conducted by the "Institut National des Mines" for SGP (Sécurité-Grisou-Poussière) explosives

Following is a brief description of these tests: *Essai A. Puissance*(Power test). A 10g sample of expl to be tested, wrapped in tin foil to form a cartridge, is placed snugly in the cavity(25mm diam and 125mm deep) formed in a lead block 200mm diam and 200mm high. After inserting a No 8 electric detonator and tamping with sand, the cartridge is exploded. The vol(in $cm^3$) of the cavity after the expln, minus the vol of the original cavity and minus the expansion caused by a No 8 detonator(ca 70cc), represents the power of an expl. This value divided by the corresponding value for PA (picric acid) and multiplied by 100 gives the *relative power* (puissance rélative)
*Essai B. Aptitude à l'explosion* (Aptitude to explosion) or *Essai de sensibilité* (sensitivity test) is conducted somewhat similarly to the American *gap test*, which is briefly described in Vol 1,p XIV, under Gap Test

In the Belg test, two cartridges of an expl to be tested are attached(in series without an air gap) to a soft iron rod(4mm diam & 0.5m long) by means of thin wires, two pieces to each cartridge. A space of at least 1cm must be provided at one end of the rod(for later attachment of a thick wires above and parallel to the ground. The first two cartridges are then exploded and if the thin wires at the other end of the rod leaving a certain air gap betw the end of the 2nd cartridge and the beginning of the 3rd cartridge. After inserting a No 8 elec detonator inside the 1st cartridge, the ensemble is taken to a special cave where the rod is suspended from a beam by two thick wires above the parallel to the ground. The first two cartridges are then exploded and if the gap to the 3rd cartridge is not too great, it will be detonated by influence. The max distance(gap) in cm at which 6 consecutive firings of the 1st & 2nd cartridges cause detonation of the 3rd cartridge is detd in this test
*Essai C. Aptitude à l'explosion après sejour dans une atmosphère humide* (Aptitude to explosion after remaining in a humid atmosphere). The previous test B is repeated with cartridges that have been previously weighed and left for several days at 18-22° inside a zinc-lined box provided with a tight-fitting cover, a grating at the bottom and a layer of water. Prior to being submitted to the gap test, the cartridges are reweighed to det the amt of absorbed moisture
*Note*: In the opinion of Dr Deffet, tests A, B & C do not suffice because they do not det the *efficiency*(rendement) of expls. The efficiency depends on several factors, such as: brisance, pressure of expln, deton velocity, velocity of development of gaseous pressure and velocity of shock wave. As some of these props are difficult, or even impossible to det, Dr Deffet proposes to include at least one of these tests, namely brisance among control tests. The method selected by Dr Deffet is the *Kast Test*, in which the compression (crushing) of a copper cylinder serves as a measure of brisance and is described in detail on p449 of the above Ref
(Description of Belgian laboratories, in which these tests are conducted, is given by L.Deffet in the journal "Explosifs", Bruxelles,1959,XII, 152*ff*)

## BELGIAN EXPLOSIVES, AMMUNITION, WEAPONS, RELATED ITEMS AND PLANTS MANUFACTURING THEM.

*Note*: For information on this subject, we are indebted to the following Belgian scientists and industrialists: 1)Dr L.Deffet, Director of the Centre de Recherches Scientifiques et Techniques pour l'Industrie des Produits Explosifs (CRIPE) and the Institute Belge des Hautes Pressions(IBHP) 2)Dr F.Lebrun of the Société Anonyme Poudreries Réunies de Belgique(SAPRB) and 3)Mr E.Tomson, Director of the Fabrique Nationale (FN) d'Armes de Guerre, at Herstal-lez-Liège

Although Belguim is a small country, its explosives and ammunition industry is quite large and Belgian small arms are famous throughout the world. Due to extensive mining industry, Belgium developed, beginning in the 1870's, many excellent coal mining expls. Belgium is also exporting large quantities of industrial expls to other countries. Some good military or civilian expls, propellants, blasting accessories, arms and ammunition are also developed or manufd in Belgium

In the field of civilian expls and blasting accessories, the various plants or companies manufg these items joined together for marketing and service to customers in Belgium in an "Association des Fabricants Belges d'Explosifs"(AFBE). This Assocn, together with the "Centre de Recherches Scientifiques et Techniques pour l'Industrie des

Produits Explosifs"(CRIPE) publishes every three months, the journal "Explosifs" dealing with scientific and technical subjects related to expls

The **Belgian Companies affiliated with the Association** and now (summer 1961) remaining the sole manufactures of civilian expls and accessories are:

1) *SA d'Arendonck*, with offices in Liège and plant in Arendonck

2) *SA de la Poudrerie Royale de Wetteren Cooppal & Cie*, with offices in Bruxelles and plants in Caulille(founded in 1778 as a black powder plant) and at Wetteren

3) *SA Fabrique Nationale de Produits Chimiques et d'Explosifs à Boncelles* (SAFNPCE), with offices and a plant in Boncelles

4) *SA de la Poudrerie d'Ombret J.P.Gerard & Cie*, with offices in Liège and a plant in Ombret

5) *SA Poudreries Réunies de Belgique*(SAPRB), with offices in Bruxelles and plants in Matagne-la-Grande, Balen, Clermont-sous-Huy and Engis

6) *SA La Sabulite*, with offices and a plant in Moustier-sur-Sambre

The companies "Poudrerie de Carnelle", "Explosifs d'Havré" and "Explosifs Yonckites" still exist in name only; their activities have been taken over by the SA Poudreries Réunies de Belgique(SAPRB). The SAPRB is also connected with the "SA Afridex" (making civilian mining expls in Katanga), "Companhia de Pólvoras e Muniçoes de Barcarena" (Portugal) "Explosivos EXSA", Perú

Among Belgian expls manufacturers, only SAPRB and the "Poudrerie Royale de Wetteren Cooppal et Cie" are exporting throughout the world expls such as Blasting Gelatin, Special Gelatins, Ammoniagelatins, Gelignites, Semi-gelatins, NG Dynamites, Ammonia Dynamites, Black Powder, fuses, etc. The SAPRB is the sole Belgian manufacturer of plain and electric (instantaneous, long delay and short delay) blasting caps, which are used not only in Belgium but in other countries as well

The **current Belgian Industrial Explosives** are classified as follows:

A) "*Gelatinous" Explosives*: a) *Dynamite Type* I [kind of ammoniagelatin of 80-85%,RWS (relative weight strength)] (manufd by SAPRB and by SA Cooppal) b) *Dynamite Type III* (kind of ammoniagelatin, 70% RWS) (SAPRB and SA Cooppal) and c) *Blasting Gelatin*, contg 93% NG(SAPRB and SA Cooppal). All these expls are very brisant

B) "*Brisant" Explosives*(non-gelatinous): a) *NG Dynamites and Explosives containing no NG* (used mainly in quarries) b) *Cooppalite TA, Cooppalite Rouge* and *Cooppalite N*(SA Cooppal) c( *Fractorite and Triamite 27*(SAPRB) d) *Nitratol and Ruptol*(SA d'Arendonck) e) *Sabulite Brisante* (SA La Sabulite) and f) *Alsilite*(SAFNPCE at Boncelles)

*Note*: Dynamites I & III, as well as the above Brisant Explosives, can also be used in non-gaseous coal mines. They are listed in Belgian Regulations as Type 1 Non Safety Mines Explosives

C) *SGP(Sécurité-Grisou-Poussière) Explosives* (Safety coal mines explosives, sheathed and unsheathed): a) *Type II of Belgian Regulations* are the following sheathed brisant explosives("Explosifs brisant gainés"): *Fractorite CA* (contains ca 10% NG)(SAPRB); *Ruptol B*(Contains ca 10% NG(Arendonck) and *Sabulite 003*(contains ca 14% *TNT* and no NG(Sabulite Plant) b) *Type III of Belgian Regulations* are the following sheathed safety expls: *Alkalite*(ca 12.5% TNT and no NG (Boncelles); *Nitro Coppalite* V(ca 10% NG)(Cooppal); *Flammivore*(ca 10% NG) (Arendonck); *Nitroboncellite*(ca 10% NG)(Boncelles); *Sabulite BV* (ca 14% TNT but no NG) (Sabulite); *Matagnite VIII*(ca 10% NG)(SAPRB); *Sécurite B*(ca 35% NG) (SAPRB) and Arendonck) c) *Type III of Belgian Regulations* includes the following high safety unsheathed expls: *Bicarbite*(ca 15% NG)(SAPRB and Arendonck); *Arionite* (Arendonck); *Nitrocooppalite VIII*(Cooppal) and *Charbrite 418*(SAPRB)

*Note*: The last three expls contain 10% NG and $NH_4Cl+NaNO_3$ instead of the customary $NH_4NO_3+NaCl$. These "exchanged ions" type safety and an excellent explosive yield

D) *Black Powder* is manufd in small quantity for use in quarrying(Cooppal & Ombret)

E) *Ammonium Nitrate Sensitized with Oil* is manufd for some quarrying operations (Ombret)

The Belgian expls listed in this section are those currently in use. There were, however, in the past many expl compositions either originating in Belgian or in use there. As the purpose of this book is to describe all kinds of expls, they will be included elsewhere in alphabetical order

The following **Belgium Expls** are expected to be described separately: *Alkalite, Alsilite, Amasite, Ammoncarbonite, Antigel de Sûreté, Antigrisou Explosifs, Antigrisous Favier(Grisoutines), Asphaline, Baelenite, Cannel Powder, Casteau (Explosifs de), Centralite RII, Centralite TA, Clermonite, Colinite-antigrisouteuse B, Cooppalite, Cooppal Poudre n°2, Delattre(Explosifs de),*

*Divine(Explosifs de), Diénite, Dynamite III, Dynamite à l'ammoniaque de Matagne-la-Grande, Dynamite-antigel de la Dynametrie d'Arendonck, Dynamite-antigrisouteuse IV(Dynamite de Sûreté), Dynamite-antigrisouteuse V(Dynamite de Baelen Wetzel), Dynamite-gomme A, Dynamite-gomme de Matagne-la-Grande, Favier(Explosifs de), Flammivores, Forcites, Fortis(Poudres d'Heusschen) Fractorites, Fulmicoton chloraté(Poudre), Gélatine a l'ammoniaque A ou n° 3, Gélatine-carbonite, Gélatine-dynamites, Gélatines explosibles, Gélatine explosive de guerre, Gélignite à l'ammoniaque, Gélignite d'Arendonck, Grisounites* (same as Antigrisous Favier), *Grisoutines, Grisoutites, Koblencarbonite, $L_3$(Poudre) de Cooppal, Macarite, Matagnites, Mégadyne, Mélanite, Minérite, Minite d'Arendonck, Minolites, Müllerite, Néoclastite, Nitrobaelinite 3, Nitrocooppalite, Nitroferrite, Oxonite, Permite, Permonite SGP, Potentite ou Tonite, Poudre amide (de Gaëns), Poudre blanche Cornil, Poudre de Bois de Wetteren, Poudre Cooppal(de chasse), Poudre Cooppal(de guerre), Poudre Curtis et André, Poudre Gaëns, Poudre Vril, Poudres de Wetteren, Pudrolithe, Pyrolithes(Pyrolythes), Pyronomes, Sabulites, Saxifragine, Sécurites, Sengithe, Stubenrauch(Explosifs de von), Superforcite, Tonite*(same as Potentite), *Tritorites, Vélterine, Wallonites, Wélterine, Wetteren(Poudre de guerre de), Xanthine(Poudre de) and Yonckites*

The following list includes **Belgian Explosives, Propellants, Ammunition and Related Items** used mostly for military purposes:

1)*Black powder* (Poudre noire)- for fuses and military purposes(Clermont plant of SAPRB and Wetteren plant of SA Cooppal)

2)*Carbines*- see under Belgian Weapons

3)*Cartridges*(Cartouches)- for small arms(FN at Herstal); for artillery(FN at Herstal, Forges de Zeebrugge and Metallurgia)

4)*Cyclotetramethylenetetranitramine*(HMX) (probably at the Balen plant of SAPRB)

5)*Cyclotrimethylenetrinitramine* (Hexogène) (RDX) (Balen plant of SAPRB)

6)*Delay and Relay Elements for Fuzes and Blasting Equipment* (Matagne-la-Grande plant of SAPRB)

7)*Detonating Cord*(Cordeau détonant)(Matagne plant of SAPRB)

8)*Detonators and Blasting Caps* for military and civilian uses(Matagne plant of SAPRB)

9)*Dinitrotoluene* (Balen plant of SAPRB)

10)*Fuses* (Wetteren plant of SA Cooppal and Engis plant of SAPRB)

11)*Fuzes* (same as above)

12)*Grenades*,SAPRB manufd hand & rifle grenades of the following types: fragmentation, tear & smoke; while UMAL, MECAR & FN manufd AP rifle grenades with shaped charges

13)*Guns*- see under Belgian Weapons

14)*Lead Azide* (LA) and *Lead Styphnate* (LSt) (Matagne plant of SAPRB and Zutendael plant of FN)

15)*Machine Guns, Machine Pistols and Submachine Guns*- see under Belgian Weapons

16)*Mercury Fulminate* (MF)(same as Lead azide plants)

17)*Mines*, such as undetectable antitank mines ATK-I, ATK-III & ATK IV with antilifting devices and undetectable antipersonnel mines AP 35M5Bg are manufd by SAPRB

18)*Mortars*- see under Belgian Weapons

19)*Nitric Acid*(Acide azotique) by the Comptoir Belge de l'Azote(COBELAZ)- 5 plants; main office at Bruxelles

20)*Nitrocellulose* (Caulille plant of SA Cooppal) (Limbourg)

21)*Nitroglycerin* (Caulille plant of SA Cooppal; Balen plant of SAPRB and Arendonck plant of SA d'Arendonck)

22)*Pistols*- see under Belgian Weapons

23)*Primers* (Amorces)(Zutendael plant of FN and Matagne plant of SAPRB)

24)*Propellants, Smokeless* (Poudres sans fumée). Clermone plant of SAPRB and Caulille plant of SA Cooppal manuf both *single- and double-base* proplnts which are mostly of the same types as currently used in the US. In time prior to wars, mostly French types(such as Poudre B & Ballistite) as well as British types(such as Cordite) were used in Belgium. Clermont plant also manuf *Ball Powder*(Poudre sphérique) while *Composite* propellants are manufd at the Balen plant of SAPRB

25)*Revolvers*- see under Belgian Weapons

26)*Rifle Grenades*- see Grenades

27)*Rifles*- see under Belgian Weapons

28)*Sulfuric Acid*(Acide sulfurique) and *Oleum* (Oléum)- by the Syndicat Belge de l'Acide Sulfurique- 16 plants; main office at Bruxelles

29)*Tetracene* (Matagne plant of SAPRB and Zutendael plant FN)

30)*Tracers* (Traceurs)(Zutendael plant of FN and Matagne plant of SAPRB)

*Note*: The SA des Explosifs d'Havré, now absorbed by SAPRB, also seems to be a manufacturer of tracers

31) *Trinitrotoluene*(Trotyl)(Balen plant of SAPRB)

32)*Weapons*- see the list below

The following list includes **Belgian Plants Currently Manufacturing Ammunition, Weapons and Related Items:**

A)*FN*(Fabrique Nationale) *d'Armes de Guerre* in Herstal(Liège), founded in 1889, one of the world's largest [various weapons such as revolvers, rifles (including the **FN** rifle adopted for NATO troops), machine guns & pistols, guns and mortars; various grenades, cartridges, jet engines, trucks, etc(see the list of Belgian ammo and weapons given below).] There is also a plant at Zutendael, which manuf LA, LSt, Tetracene, primers and tracers

B)*SA Belge de Mechanique et d'Armement* (MECAR) at Petit-Roeulx [various shaped charge ammunition and weapons, including the Energa rocket grenade, the 90mm A/T gun, called CATI, and the A/T weapon called Blindicide(qv)]

C)*SAPRB* (SA des Poudreries Réunies de Belgique) at the Balen plant(loading and assembling of various kinds of ammunition, such as artillery, mortars, grenades, mines, rockets, etc); at the Matagne-la-Grande plant(various fuzes, primers and tracers)

*Note:*The SA de Explosifs d'Havré plant, manufg tracers etc, is now absorbed by SAPRB

A gallery for testing coal-mining expls is loca- at Balen

D)*Forges de Zeebrugge* at Liège(metal parts for artillery & mortar ammunition and for rockets)

E)*UMAL*(Usines et Métallurgie d'Aluminium et d'Alliages Légers) at Burcht (near Antwerpen) (manuf same items as MECAR)

F)*Metallurgia*(Malines), subsidiary of SAPRB (metal parts for artillery ammo, including steel cartridges cases, especially perforated ones)

The following list includes *Belgian official laboratories and facilities for testing explosives, ammunition and Weapons*(excluding control laboratories):

a)*Arsenal de Munitions* at Zwyndrecht (near Antwerpen) (Inspection labs for military expls, propellants and ammo)

b)*Belgian Army Proving Grounds* at Brasschaet (near Antwerpen) and at Elsenborn(near the German border)

c)*CRIPE* (Centre de Recherches Scientifiques et Techniques pour l'Industrie des Produits Explosifs) in Sterrebeek(near Bruxelles)(Testing of industrial expls)

d)*IBHP* (Institut Belge des Hautes Pressions), Tir National, Bruxelles

e)*Institut National des Mines* in Paturages(near Mons)(gallery for testing expls and accessories intended for use in gaseous or dusty coal mines)

The following list includes the principal *Belgian weapons* manufd in the past and at present by FN at Herstal and by some other plants:

1)*Revolvers and Pistols*, Nagant Revolver cal 9mm(.354"), was adopted in 1878 for officers and a slightly modified model was adopted in 1883 for non-commissioned officers

*Note:* Nagant revolvers, cal 7.5 & 7.62mm, have been used in Russia for about 70 years

These revolvers were superseded in Belgium by the FN Browning Automatic Pistol, Mod 1910, cal 7.62mm(.32"), magazine capacity 7 rounds. This pistol was in turn superseded ca 1935 by the FN Browning High Power Pistol, cal 9mm, 13 rounds, which is still in use. FN is also manufg a 6.35mm and a 7.65mm automatic pistol

*Note*: Many other automatic pistols, ranging in caliber from .25" to .38", have been manufd by FN, most of them for export. The same may be said of other pistols formerly manufd in Belgium at smaller plants, such as the Bayard, Clement, Pieper, etc. All these plants were absorbed by the FN

2)*Rifles*(Non-Automatic). Albini-Broendlin, cal 60", single-shot rifle, was the first Belg breech-loader. It was used since 1867. The next single--shot rifles were Gras Mod 1874, cal 11mm and Comblain Mod 1881, cal 11.6mm. The latter rifle was used by the Belg Civil Guards as late as WWII. .These rifles were replaced by the Mauser, Mod 1889, cal 7.65mm, magazine capacity 5 rounds, rifle and carbine. They fired round-nosed bullets.

After WW I, the Mauser rifles, Gewehr '98, cal 7.92mm, taken from the Germans, were converted in Belgium to the cal 7.65mm rifle. These were known as the Mauser Mod 1935. A similar rifle, known as Mauser Mod 1936, was obt by modifying the Belg Mauser Mod 1889, Both of these models fired pointed bullets and some were used as late as WWII

In addn to Mauser rifles, such as cal 7.9mm, there were also some reworked Brit & US rifles of WWI, such as cal .303" Lee-Enfield rifle

*Note:* While the regular Belgian Army is now equipped with automatic rifles (see below), the non-automatic rifles, system Mauser and Lee-Enfield, are still in use by the Belg Gendarmerie, Police and Customs

3) *Rifles, Automatic* (Light Machine Guns). Chauchat Machine Rifle, cal 7.65mm, known as

Mod 15 (Fusil Mitrailleur CSR6), fired round-nosed bullets and had magazine capacity of 15 rounds. It was used during WWI and later replaced by the FN Browning Rifle Mod 30, cal 7.65mm, mag capacity 20 rounds, which fired pointed bullets

More recent types of Belg automatic rifles include: FN Browning Automatic rifle, cal 30"; Bren Gun, cal .303" and FN Light Automatic Rifle, cal 7.62mm, magazine capacity 20 rnds; this rifle, designated as *FAL* is now used by Belgian and NATO troops. There is also the FN Self-Loading Rifle, cal .30", magazine capacity 10 rounds. It is designated as *AFN cal 30"*

4) *Machine Guns(Light & Medium) and Machine Pistols.* Mitrailleuse(multibarrel), designed in 1851 by Capt Fafschamps of the Belgian Army and improved by Montigny, a Belg engineer, was never used by the Belgians but was adopted by the French in 1867. Berthier-Pasha MG, invented in 1908 by the French officer A.Berthier, was produced in small numbers for the US Govt during WWI by the now extinct Belgian firm of Pieper in Herstal

The first MG used by the Belg Army was the Maxim 08, cal 7.65mm, water-cooled. This gun was used from before WWI until WWII. During WWI the Belgians also used some Colt MG, Mod 1895, cal 7.65mm, firing round-nosed bullets. This gun was designed by John Browning, an American. A later model fired pointed bullets. Modification of Maxim 08/15(water-cooled) and Maxim 08/18(air-cooled), both cal 7.65mm and obtd from the Germans after WWI, were used by the Belgians during WWII and then discarded

The more recent weapons include: FN MAG Machine Gun, cal 7.62mm NATO, belt fed(steel); FN Machine Pistol, cal 9mm Parabellum, magazine capacity 25 or 32 rounds; Browning MG, cal .50", belt fed(Mitrailleuse .50-A-Avi), corresponding to the US Browning .50"M2

5) *Sub-Machine Guns.* Sten Gun, cal 9mm, magazine capacity 28 rounds; Vigneron Gun, cal 9mm, mag capacity 32(not manufd by FN) and Thompson Gun, cal 45", mag capacity 32. FN is now manufg for Belg Army the 9mm Parabellum type sub-machine, Designated *UZI*

*Note*: Schmeisser-Bergmann sub-machine gun, cal 9mm, adopted in the thirties, was manfd by Pieper Co; discarded after WW11

6) *Machine Guns, Heavy.* 20mm Oerlikon and Hispano-Suiza MG's

7) *Guns(Cannons) and Howitzers:* 40mm Bofors L60 Gun; 47mm Single-shot A/T Gun(discarded after WWII ; 57mm A/T Gun(semi-automatic fire); 57mm Bofors Gun; 75mm Field Guns; 76mm Guns; 90mm A/T Gun, Mod 1(called CATI); 105mm Gun; 105mm Howitzer; 120mm Gun, M31; and 8-inch Gun

8) *Mortars:* 2-inch Mortar; 60mm Mortar(US); 3-inch Mortar; 81mm Mortar(US); 4.2-inch Mortar (US M2); and 4.2-inch Mortar(British Heavy)

*Note*: During WWI, a Belg officer Van Deuren invented a mortar which was used during WWII but was discarded afterward

9) *Rocket Launchers.* 83mm *Blindicide* for firing the *Energa* rocket, called ROCK-HEAT 83mm

*Note*: Energa rockets are described in conf PATR(Picatinny Arsenal Technical Report) **2097** (1954) and in PAMR's(PicArsnMemorandum Repts) **80**(1955), **86**(1955) and **86**(Supplement)(1956)

10) *Grenade Launchers.* Grenade Launcher *DBT*, invented in Belgium betw WWI and WWII, consisted essentially of a Mauser breech mechanism on which was screwed the launching cup

**Bellenite.** An expl based on nitrolignin and manufd in Sydney, Australia at the beginning of this century

*Ref*: Daniel(1902), 58

**Bellford Powder,** patented in 1853 in England, was prepd by impregnating the grains of black powder with a satd soln of K chlorate and then drying for 4 days at 100°F

*Refs:* 1)Cundill(1889) in MP **5**,292(1892) 2)Daniel(1902),59

**Bellites** are expls consisting of AN and mono- or di-nitrobenzenes(*MNB* and *DNB*). Many modifications exist and some compns contain K nitrate instead of AN. The original *Bellite*: AN 34.5 & MNB 65.5%, was proposed ca 1885 by C.Lamm of Sweden and was manufd at Rotebro, near Stockholm. Bellites were patented in 1885 in England and manufd by the Lancashire Explosives Co,Ltd. Marshall(Refs 4 & 5) gives compns of the following British "permitted" Bellites:

| Bellites | AN | DNB | NaCl |
|---|---|---|---|
| No 1 | 83.5 | 16.5 | - |
| No 2 | 93.5 | 6.5 | - |
| No 3 | 61 | 12 | 27 |
| No 4 | 66 | 14 | 20 |
| No 1a | 68 | 12 | 20 |

The No 1 & No 2 compns are also listed by Cook(Ref 9). They passed the Woolwich Test. The No 3 & No 4 compns passed the Rotherham Test, whereas the No 1a passed the Buxton Test

Kostevitch(Ref 4a) gives for a Rus Bellite used during WW1 in bombs and grenades: AN83 & DNB 17%. A Rus Bellite(Belit) listed in Ref 8 consisted of AN 80, DNB 8 & TNX 12%

The so-called Black Bellite consisted of AN 61, TNT 12, NaCl 24 & native graphite(plumbago) 3% (Ref 6a)

Bellites were manufd by heating the well-mixed ingredients to above the mp of the nitrocompd to completely coat the AN(or K nitrate) crysts with nitrocompd in order to render them non-hygroscopic. The mixt was pressed into cartridges while still hot

*Refs*: 1)Cundill(1889) in MP **5**,292(1892) 2)Daniel(1902), 59-60 3)Gody(1907), 596 4)Marshall **1**(1917), 388-90 4a)M.M.Kostevitch, "Burning Ground", Imp d'Art Voltaire, Paris (1927),40 5)Marshall **3**(1932), 119 6)Thorpe **4**(1940), 465 & 554 6a)CondChemDict(1942),288 (not found in later editions) 7)Bebie(1943), 32 8)Shilling(1946), 97-8 9)Cook(1958),10

**Bellot, Nicolas**(1792-1882). A Ger expls chemist who may be considered as a designer of the modern percussion cap. He founded in 1829 the firm of Sellier & Bellot, which later was renamed Zündhütchen- und Patronenfabrik

*Ref*: Anon, SS **24**, 271(1929)

**Bell Powder**, patented in England in 1898, contained K nitrate 70.2, pulverized coal 18 & sulfur 11.8%

*Ref*: Daniel(1902), 58

**Bender Explosive.** An older Fr expl, known also as Grisoutine Comprimée

*Ref*:Daniel(1902), 363

**Benedict Explosives** were compns intended to replace MF in primers and detonators. The following compns are described in the literature: *Simple*: K chlorate 38.70, P(amorphous) 19.35, minium($Pb_3O_4$) 38.70 & rosin 3.25%; *Double*: K chlorate 79.18, P(amorphous) 8.33, Sb trisulfide 8.33, S(sublimed) 2.08 & K nitrate 2.08%. Minium could be replaced by HgO or Mn dioxide

*Refs*: 1)Cundill(1889) in MP **5**,292(1892) 2)Daniel(1902),60-1 3)Pérez Ara(1945), 207

**Benedite.** An AN expl permitted in England since 1898: AN 93-95 & rosin 7-5(Ref, p 61). It was identical with the Ger expl *Westfalit Nr 1*, described in Ref,p 804

*Ref*: Daniel(1902), 61 & 804

**Beneké Explosives**, patented in England in 1896, were prepd by melting rosin and mixing it with 1-1.5 parts of finely pulverized K bichromate and 1-1.5 ps Na carbonate or bicarbonate. After cooling, the mass was pulverized, mixed with additional 4-5 ps of rosin and 93-94 ps of AN and reheated to coat the AN crysts with rosin. These expls were relatively non-hygroscopic. Other Beneké expls consisted of liq hydrocarbons mixed with K bichromate(or chlorate, or permanganate) and finely pulverized charcoal. An expl patented in 1900 consisted of AN and some K chlorate

*Ref*: Daniel(1902), 62-3

**Benét-Mercié Automatic Rifle** was developed in 1908 and adopted in 1909 by the US Army. It was the forerunner of the Browning automatic rifle, used since 1917

*Ref*: J.J.O'Conner, Ordn **37**, 271(1952)

**Bengal Fire Powder.** A mixt used during WWI for signalling purposes: Ba nitrate 67, Amm picrate 25 & sulfur 8%. It burned with an intense green flame. By substituting Sr nitrate for Ba nitrate a red flame was produced

*Ref*: Colver(1918),341

**Bengaline** was a powder contg K chlorate 40 & bran 60%, proposed in 1882 by Medail

*Ref*:Daniel(1902),63

**Benite.** See under Black Powders Containing Potassium Nitrate

**Bennet Powder**, patented in 1861 in England, was a black powder in which 7% of lime was incorporated

*Ref*: Daniel(1902),63

**Bent & Talley Explosives**, patented in 1909(USP 943589), included several formulations, among them: AN 50-80, NG 2-10, Mn dioxide 7-20, comminuted Zn("blue powder") 7.2-23.5 & Zn oxide 0.8-2.5%. They might also contain starch, charcoal, MNN, PA, etc

**Bent Barrel Gun or Around the Corner Gun** is described as **Krummerlauf** in PATR **2510**(PB 161270)(1958),p Ger 103. It must be noted that a similar bent barrel was patented during WWI by J.Wister, USP 1187218(1918) but it was inferior to the Ger device
*Ref*: P.P.Sharpe, "The Rifle in America", Funk & Wagnalls,NY(1947),38-40

**Bentonite or Activated Clay.** A broad term applied to material which has been derived from volcanic ash in which the mineral Montmorillonite predominates. Bentonite was first recognized in 1898 in Fort Benton(Wyoming) shales and has since been found in thick-bedded deposits over a wide area in Western US(Ref 1)

According to Kirk & Othmer(Ref 4), these clays when activated by an acid treatment, consist of 52% $SiO_2$, 14% $Al_2O_3$, 4% MgO, 2.5% $Fe_2O_3$ and small quantities of other oxides

Bentonites may generally be divided into two classes: a) Those capable of absorbing large amts of water and which swell tremendously in the process. They also have the property of remaining in suspensions in thin water dispersions and b) Those that absorb no more water than ordinary plastic clays or Fuller's earth and do not swell appreciably. They settle rapidly in thin water dispersions

The raw Bentonite consists of about 10% particles larger than 10$\mu$ and about 70% smaller than 0.5$\mu$. One gram has a total surface area of ca 50000$cm^2$. A high-grade Bentonite will absorb nearly 5 times its wt of w and will increase in vol up to 15 times its dry bulk. The swelling process is reversible if less than 10% of alkali is present. With 6-7 parts of w Bentonite forms a gelatinous paste and with 20ps of w it forms a thin sol which is stable for months. When 2ps of wet Bentonite are blended with 1p of wet Cu acetylide, the mixt can be air-dried w/o expln and used as a fungicide(Ref 5)

Bentonites have been used for clarifying and bleaching oils, for emulsifying asphalts & other water immiscibles, as a suspending, thickening or paste-forming agent and for other purposes. It has been suggested as an emulsifier in some expl compns and as an absorbent of some liq expls(see Note). Some of the Aerojet Engineering Corp proplnts contain Bentonite. Eg: *RL-206 Propellant* consists of Paraplex AP-31 27.35, styrene 27.35, Bentonite 44.76 & t-butyl hydrogen peroxide 0.54%(Ref 3)
*Note*: Although Bentonite is a good absorbent for liq expls(it absorbs twice as much NG as diatomaceous earth), the presence of gritty particles has limited its use from a safety standpoint

US military requirements for Bentonite are covered by Specifications MIL-B-12208A(CE) and MIL-B-10456A(CmlC)
*Refs*: 1)Thorpe **1**(1937),663-4 2)USBurMines TechPaper **609**, "Bentonite; Its Properties, Mining, Preparation and Utilization"(1940) 3)Aerojet Engineering Corp Rept No **192**(1946), 17 4)Kirk & Othmer **1**(1947),229(under Absorption) and **4**(1949), 28 & 53(under Clays) 5)M.W. Swaney, USP 2521424(1950) & CA **44**, 11010 (1950)

**Benton's Electro-Ballistic Pendulum.** An instrument used in Springfield Armory and Frankford Arsenal in the 1870's for detn of velocities of projectiles. A modified model was known as Thread Velocimeter
*Ref*: J.G.Benton, "Description of Thread Velocimeter", Springfield National Armory, Springfield, Mass(1873)

**Benzalaminoguanidine-1,6-dinitro-2-(aminoguanil)-biguanidine benzalhydrazone.** See Vol 1,p A215-L

**Benzalaminophenol.** See Benzylideneaminophenol

**1-Benzalamino-5-phenyl-$\alpha$(or 1H)-tetrazole or 1-Benzylindene-amino-5-phenyl-$\alpha$(or 1H)-tetrazole,** $C_6H_5.\underset{\underset{N}{\|}}{C}\text{-}N(N{:}CH.C_6H_5)\text{-}\underset{\underset{N}{\|}}{N}$, mw 249.27, N 28.10%; ndls(from alc), mp 105°; expl mildly on rapid heating above mp; mod sol in eth or alc; diffc sol in hot w. Can be prepd by heating on a steam bath benzazide-benzalhydrazone in alc or by heating benzylidene-[$\alpha$-chlorobenzylidene]-hydrazine with $NaN_3$ in alc(Refs 1,2 & 3)
*Refs*: 1)Beil **26**,(113) & [216] 2)R.Stollé & F.Hellwerth,Ber **47**,1139(1914) 3)R.Stollé & A.Netz,Ber **55**,1300(1922) 4)R.Stollé et al, J.PraktChem **138**,3(1933) & CA **27**,4798(1933)

**5-Benzalamino-2-phenyl-$\beta$(or 2H)-tetrazole or 5-Benzylidene-amino-2-phenyl-$\beta$(or 2H)-tetrazole,** $C_6H_5.CH{:}N.\underset{\underset{N}{\|}}{C}{=}N\text{—}\underset{\underset{N}{\|}}{N}.C_6H_5$, mw 249.27, N 28.10%; ndls(from alc), mp 123° (with browning); mod sol in eth; sol in alc; insol in w. Can be prepd by heating on a steam bath 2-phenyl-5-aminotetrazole with an excess of benzaldehyde(Refs 1 & 2)
*Refs*: 1)Beil **26**,[344] 2)R.Stollé & O.Otth,Ber **58**,2104(1925)

**Benzalaniline.** See Benzylideneaniline

**Benzalazine.** Same as Banzaldehyde Azine

## BENZALDEHYDE AND DERIVATIVES

**Benzaldehyde** *(Phenylaldehyde; Benzene Carbonal* or *Artificial Almond Oil)* (called l'-Oxo-1-methyl -benzol; Benzaldehyd or Bittermandelöl in Ger), $C_6H_5.CHO$; mw 106.12, col liq, mp -26° (resolidifies at -56°), bp 179°, d 1.046 at 20°; sol in alc or eth; sl sol in w; vap press data in Ref 4. Its toxicity and hazards are described by Sax(Ref 5). Benzaldehyde is produced commercially by the catalytic oxidn of toluene(Refs 2 & 3); other methods of prepn are given in Beil(Ref 1). Its trinitroderiv is expl

*Refs*: 1)Beil **7**,174(113) & [145] 2)L.D.Margolis, ZhPriklKhim **14**,827-31(1941) 3)Kirk & Othmer **2**(1948),416 4)Jordan(1954),92 & 106 5)Sax(1957), 342

*Azidobenzaldehyde*, $N_3.C_6H_4.CHO$, mw 147.13, N 28.56%. The o-(or 2)-azido deriv, plates, mp 37.5°, is listed in Beil **7**,266 & (145)

**Azobenzaldehyde.** See Vol 1,p A646-R

**Azoxybenzaldehyde and Derivatives.** See Vol 1, p A666-L

*Nitrosobenzaldehyde*. The o(or 2)-, m(or 3)- and p(or 4)- derivs are described in Beil **7**,242 & (136)

### Nitro Derivatives of Benzaldehyde

**Mononitrobenzaldehyde**, $O_2N.C_6H_4.CHO$; mw 151.12, N 9.27%, OB to $CO_2$ -143%. Three isomers are described in Beil: *o(or 2)-Nitrobenzaldehyde*, yel ndls, mp 43.5-46°, bp 153°; v sl sol in alc or eth. Prepn and other props in Ref 1; *m(or 3)-Nitrobenzaldehyde*, yel ndls, mp 57.5-59°, bp 164°; sol in alc, eth or chlf; so sol in w. Prepn and other props in Ref 2; *p(or 4)-Nitrobenzaldehyde*, yel prisms, mp 104.3-106.5°; $Q_C^V$ 793 cal/mol or 5251 cal/g(Ref 4). Prepn and other props in Refs 3 & 5

*Refs*: 1)Beil **7**,243,(136) & [185] 2)Beil **7**,250, (139) & [190] 3)Beil **7**,256,(141) & [196] 4)W.H. Rinkenbach,JACS **52**,116(1930) 5)W.Davey & J.R.Gwilt,JCS **1950**,204-8

**Dinitrobenzaldeyhde**, $(O_2N)_2C_6H_3CHO$; mw 196.12, N 14.29%; OB to $CO_2$ -89.2%. Two isomers are described in Beil: *2,4-Dinitrobenzaldehyde*, yel prisms, mp 72°; bp 190-210° at 10mm; sol in benz; insol in alc, eth or w. Prepn and other props in Refs 1 & 3. *2,6-Dinitrobenzaldehyde*, yel lfts (from dil AcOH), mp 123°. Prepn and other props in Ref 2

*Refs*: 1)Beil **7**,264 & [205] 2)Beil **7**,(144) & [206] 3)OrgSynthColl Vol **2**(1943),233

**2,4,6-Trinitrobenzaldehyde** (TNBA), $(O_2N)_3C_6H_2.CHO$; mw 241.12, N 17.43%, OB to $CO_2$ -56.4%; col plates (from benz), mp 119°, $Q_C^V$ 732 cal/mol or 3035cal/g (Ref 3); sol in w or benz. Can be prepd by several methods(Refs 1 & 2). One of the best methods of prepn is the acid hydrolysis of the condensation product of TNT with p-nitroso-dimethylaniline: $(O_2N)_3C_6H_2CH{:}N.C_6H_4.N(CH_3)_2+H_2O \rightarrow (O_2N)_3C_6H_2.CHO+H_2N.C_6H_4.N(CH_3)_2$. The by-product is p-aminodimethylaniline

Trinitrobenzaldehyde is a HE about as powerful as TNT, but less powerful than PA. It is sl more brisant than TNT(ca 117%) as detd by the Sand Test(Refs 4 & 5). The min chges of MF or LA reqd for its deton are about 50% of those reqd for TNT. Present manufg costs prohibit the use of TNBA as a coml or military expl. TNBA forms many condensation products with org compds, some of which are expls(Ref 2)

*Refs*: 1)Beil **7**,265 & [207] 2)A.Lowy & E.H. Batz,JACS **43**,343(1921) 3)W.H.Rinkenbach,JACS **52**,116(1930) 4)L.V.Clark,IEC **25**,1387(1933) 5)Blatt,OSRD **2014**(1944)

### Other Derivatives of Benzaldehyde

**Benzaldehyde-3-diazoniumchloride**, $OHC.C_6H_4.N(:N)Cl$. Its stannic chloride salt, $[2OHC.C_6H_4.N(:N)Cl + SnCl_4]$, col ndls, mp expl mildly on heating in a flame; was prepd from 3-nitrobenzaldehyde, stannous chloride in concd HCl and Na nitrite, as described in Refs 1 & 2

*Refs*: 1)Beil **16**,538 2)F.Tiemann & R.Ludwig, Ber **15**,2045(1882)

**2,6-Dinitrobenzaldehyde-4-diazoniumchloride**, $OHC.C_6H_2(NO_2)_2.N(:N).Cl$; mw 258.58, N 21.67%; lt yel ppt; mp expl on heating without melting; readily sol in w; insol in common org solvs. Can be prepd from 2, 6-dinitro-4-amino-benzaldehyde-oxime in abs alc and HCl by reaction with amyl nitrite. Other props are given in Refs 1 & 2

*Refs*: 1)Beil **16**,538 2)F.Sachs & H.Kantorowicz, Ber **39**,2762(1906)

### Benzaldehydeazine and Derivatives

*Benzaldehydeazine; Benzalazine; Benzylideneazine; or Dibenzalhydrazine* (called Dibenzalhydrazin; Benzaldazin; sym-Diphenylazimethylen; and Dibenzylidenhydrazin in Ger), $C_6H_5.CH{:}N.N{:}CH.C_6H_5$; mw 208.25, N 13.45%, is described in Beil **7**,225,(123) & [171]

**N-[(α-Azidobenzylidene)-N'-benzylidene]-azine** (called Benzazidbenzalhydrazon in Ger), $C_6H_5C(N_3){:}N.N{:}CH.C_6H_5$; mw 249.27, N 28.10%; yel ndls(from eth or alc); mp 72°, expl at higher temp on rapid heating; sol in eth or alc; insol in w.

It was first prepd in 1914 by Stollé & Helwerth (Ref 2) by treating benzalbenzenylhydrazone-hydrazide with nitrous acid. A more convenient method(Refs 3 & 4) is to heat for about 1 hr, under a reflux condenser, an alc soln of benzalbenz-hydrazidechloride, $C_6H_5.C(Cl):N.N:CH.C_6H_5$, and then to cool the resulting mixt to ppt the crysts

This compd is a mild expl but it may serve as a starting material for the prepn of the derivs of 1-aminotetrazole, namely 1-amino-5-phenyltetrazole

*Refs*: 1)Beil **9**,(136) 2)R.Stollé & F.Helwerth,Ber **47**,1139(1914) 3)R.Stollé & A.Netz,Ber **55**,1297 (1922) 4)R.Stollé et al, JPraktChem **138**,3(1933)

*Mononitrobenzaldehydeazine*, $C_{14}H_{11}N_3O_2$, mw 253.25, N 16.59%. Three isomers are described in Beil **7**,249,255,261 & (140)

*Dinitrobenzaldehydeazine*, $C_{14}H_{10}N_4O_4$; mw 298.25, N 18.79%. Three isomers are described in Beil **7**, 250,255,261 & (138,140,143)

**4,4'-Dinitramino-3,5,3',5'-tetrabromo-benzaldehyde-azine**, $O_2N.HN.C_6H_2.Br_2.CH:N.N:CH.Br_2C_6H_2.NH-.NO_2$; mw 643.93, N 13.05%; ndls(from alc), mp expl on heating. Was prepd by treating 3,5-dibromo -4-nitramino-benzaldehyde with an aq soln of hydrazine sulfate

*Refs*: 1)Beil **16**,[348] 2)L.Elion,Rec **42**,160(1923)

**Tetranitrobenzaldehydeazine** {called Bis-[dinitro -benzal]-hydrazin or Tetranitro-benzaldazin in Ger}, $C_{14}H_8N_6O_8$, mw 388.25, N 21.65%. Two isomers are described in the literature:

*2,4,2',4'-Tetranitrobenzaldehydeazine*, $(O_2N)_2C_6H_3.CH:N.N:CH.C_6H_3(NO_2)_2$, golden-yel ndls(from hot MNB,) mp 246°; insol in alc. Can be prepd by treating an alc soln of 2,4-dinitrobenzal-dehyde with hydrazine sulfate in the presence of aq Na acetate. Its expl props were not investigated

*Refs*: 1)Beil **7**,265 2)F.Sachs & R.Kempf,Ber **35**, 1233(1892)

*2,6,2',6'-Tetranitrobenzaldehydeazine*, $(O_2N)_2.C_6H_3.CH:N.N:CH.C_6H_3(NO_2)_2$, yel ndls (from acet), mp 246-7°; easily sol in MNB, sol in glac AcOH or acet; diffc sol in alc, eth, chlf or ligroin. Can be prepd as above from 2,6-dinitro-benzaldehyde. Its expl props were not investigated

*Refs*: 1)Beil **7**,(144) 2)S.Reich & G.Gaigailian, Ber **46**,2385(1913)

### Benzaldehydeoxime and Derivatives

*Benzaldehydeoxime* (called Benzaldoxim in Ger), $C_7H_7NO$, mw 121.13, N 11.56%. It exists in two configurations $\alpha$-or benz-anti-aldoxime and $\beta$- or benz-syn-aldoxime. Both forms are described in Beil **7**,218,221,(121) & [167,169]

**Azidobenzaldehydeoxime**, $N_3.C_6H_4.CH:N.OH$; mw 162.15, N 34.56%. Two isomers are described in the literature: *2-Azidobenzaldehydeoxime*, col ndls (from benz), mp 103-103.5°; readily sol in hot benz or hot ligroin; can be prepd in several ways(Refs 1 & 3) and *4-Azidobenzaldehydeozime* as $\alpha$- and $\beta$-forms. The $\alpha$-form exists as tablets(from dil alc), mp 98°, readily sol in petr eth or in most other solvs. The $\beta$-form exists as yel ndls(from benz), mp 142° (dec), readily sol in most common org solvs except benz or petr eth. Its methyl ether is described in Ref 1. The prepn and other props of both the $\alpha$- and $\beta$-forms are described in Refs 2&4

*Refs:* 1)Beil **7**,266 2)Beil **7**,266 & (145) 3)E.Bamberger & E.Demuth,Ber **34**,1336(1901) 4)M.O.Forster & H.M.Judd,JCS **97**,257(1910)

*Mononitrobenzaldehydeoxime*, $O_2N.C_6H_4.CH:N.OH$, mw 166.13, N 16.88%. Three isomers are described in Beil **7**,248,249,254,255,259,(138,139,142) &[188, 192,193,198,199]

*Dinitrobenzaldehydeoxime*, $(O_2N)_2C_6H_3.CH:N.OH$, mw 211.13, N 19.90%. Two isomers are described in Beil **7**,265,(144) & [206]

**2,4,6-Trinitrobenzaldehydeoxime**, $(O_2N)_3C_6H_2.CH:N.OH$; mw 256.13, N 21.88%. Crysts(from alc), mp 158°; easily sol in alc or acet; insol in w. Can be prepd by treating 2,4,6-tri-nitrobenzaldehyde with hydroxylaminehydrochloride in alc soln in presence of soda. Its expl props were not investigated

*Refs*: 1)Beil **7**,265 2)F.Sachs & W.Everding,Ber **36**,961(1903)

**2-Nitrobenzaldehydeoxime-4-diazoniumchloride**, $HO.N:CH.C_6H_3(NO_2).N(:N).Cl$; mw 228.60, N 24.51%; pink ndls, mp stable at 60-80° but expl on strong heating. Can be prepd from 2-nitro-4-amino-phenyl acetic acid in cold concd HCl by reaction with amyl nitrite. On heating with alc, this compd forms 2-nitrobenzaldehyde-anti-oxime(qv)

*Refs*: 1)Beil **16**,538 2)S.Gabriel & R.Meyer,Ber **14**,826 & 2334, Footnote 1(1881)

**3-Nitrobenzaldehydeoxime-4-diazoniumchloride**, $HO.N:CH.C_6H_3(NO_2).N(:N).Cl$; mw 228.60, N 24.51%; red plates or ndls, mp expl on heating. Can be prepd by treating amyl nitrite with 3-nitro-4-amino-phenyl acetic acid in a mixt of HCl, eth & alc. On heating with alc, this comp forms 3-nitrobenzaldehyde-anti -oxime

*Refs*: 1)Beil **16**,538 2)S.Gabriel,Ber **15**,837(1882)

**$\beta$-Benzaldehydeoxime-picrylether**, $C_6H_5.CH:N.O.C_6H_2(NO_2)_3$; mw 332.23, N 16.87%; yel prisms(from acet), mp 181-2°(dec); prepn and other props in Refs 1 & 5. Its three mononitro

derivs are described in the literature: *2-Nitro-β-benzaldehydeoxime-O-picrylether,* pale yel prisms (from aq acet), mp 157-8°(dec)(Refs 2 & 5); *3-Nitro-β-benzaldehydeoxime-O-picrylether,* pale yel crysts(from acet), mp 169° (dec) (Refs 3 & 5) and *4-Nitro-β-benzaldehydeoxime-O-picrylether,* pale yel prisms(from acetone), mp 168° (dec)(Refs 4 & 5). Prepn and other props are given in the Refs. These compds are probably mild expls

*Refs*: 1)Beil **7**,[170] 2)Beil **7**, [189] 3)Beil **7**, [195] 4)Beil **7**, [200] 5)L.Brady & L.Klein,JCS **127**,846-7(1925)

**Benzaldehydephenylhydrazone and Derivatives**

*Benzaldehydephenylhydrazone* (called Benzyliden-phenylhydrazin; Benzal-phenyl-hydrazin or Benzaldehyd-phenylhydrazon in Ger), $C_6H_5.NH.N:CH.C_6H_5$, mw 196.24, N 14.28%, is described in Beil **15**,134,(31) & [57]

*2-Azido-benzaldehydephenylhydrazone,* $C_6H_5.NH.N:CH.C_6H_4.N_3$, mw 237.26, N 29.52%; yel prisms(from alc), mp 101.5-102°; readily sol in benz, hot ligroin and alc; prepn in Ref 2

*Refs*: 1)Beil **15**,138 2)E.Bamberger & E.Demuth, Ber **34**,1335(1901)

*4-Azido-benzaldehydephenylhydrazone,* $C_6H_5.NH.N:CH.C_6H_4.N_3$, mw 237.26, N 29.52%; straw-colored crysts(from methanol), mp 190°(although effervescence begins at 120°); readily sol in acet, benz, et acet or chlf; prepn in Ref 2

*Refs*: 1)Beil **15**,(33) 2)M.D.Forster & H.M.Judd, JCS **97**,260(1910)

*Benzaldehyde-(N-nitroso-phenylhydrazone),* $C_6H_5.(NO).N:CH.C_6H_5$; mw 225.24, N 18.66%, is described in Beil **15**,(104)

*Mononitrobenzaldehydephenylhydrazone,* $C_{13}H_{11}N_3O_2$, mw 241.24, N 17.42%. Three isomers are described in Beil **15**,136,137,(32,33) & [58,59]

*Dinitrobenzaldehydephenylhydrazone,* $C_{13}H_{10}N_4O_4$, mw 286.24, N 19.58%. Two isomers are described in Beil **15**,138,(33) & [59]

**2,4,6-Trinitrobenzaldehydephenylhydrazone,** $C_6H_5.NH.N:CH.C_6H_2(NO_2)_3$; mw 331.25, N 21.14%. Red-brn ndls, mp 202°; easily sol in hot acet & in AcOH; very diffc sol in alc, eth or benz. Can be prepd from benzaldehyde and phenylhydrazine in AcOH soln. It is probably a mild expl

*Refs*: 1)Beil **15**,138 & (33) 2)F.Sachs & W. Everding, Ber **36**,960(1903)

**Benzaldehyde-Nitrophenylhydrazone and Derivatives**

*Benzaldehyde-nitrophenylhydrazone,* $O_2N.C_6H_4.NH.N:CH.C_6H_5$. Three isomers are described in Beil **15**,455,461,470,(127,129,132) & [178,182,187]

*2-Azidobenzaldehyde-(4-nitrophenylhydrazone),* $O_2N.C_6H_4.NH.N:CH.C_6H_4.N_3$; mw 282.26, N 29.78%. Orn-red ndls(from alc), mp 191-2°(dec); moderately sol in hot amyl alc, hot benz or hot alc; diffc sol in ligroin. Can be prepd from 2-azidobenzaldehyde and 4-nitrophenylhydrazone hydrochloride in alc soln. It is probably a mild expl

*Refs*: 1)Beil **15**,471 2)E.Bamberger & E.Demuth, Ber **34**,1335(1901)

*Mononitrobenzaldehyde-nitrophenylhydrazone,* $O_2N.C_6H_4.NH.N:CH.C_6H_4.NO_2$; mw 286.24, N 19.58%. Nine isomers are described in Beil **15**,455,461-2,470,(127,133) & [178,182,188]

*Dinitrobenzaldehyde-nitrophenylhydrazone,* $O_2N.C_6H_4.NH.N:CH.C_6H_3(NO_2)_2$, mw 331.24, N 21.14%. Three isomers are described in Beil **15**,470,(127,133) & [188, 189]. These compds are probably mild expls

**2,4,6-Trinitrobenzaldehyde-(4-nitrophenylhydrazone),** $O_2N.C_6H_4.NH.N:CH.C_6H_2(NO_2)_3$; mw 376.24, N 22.34%. Bright-red ndls(from hot acet); mp 247°; easily sol in et acet or MNB; v sl sol in alc, chlf or glac AcOH. Can be prepd from 2,4,6-trinitrobenzaldehyde and 4-nitrophenylhydrazone as described in Ref 2. Its expl props were not investigated

*Refs*: 1)Beil **15**,471 2)F.Sachs & W.Everding, Ber **36**,961(1903)

**Benzaldehyde-dinitrophenylhydrazone and Derivatives**

*Benzaldehyde-(2,4-dinitrophenylhydrazone),* $(O_2N)_2C_6H_3.NH.N:CH.C_6H_5$; mw 286.24, N 19.58%. is described in Beil **15**,491 & [217]

*Mononitrobenzaldehyde-(2,4-dinitrophenylhydrazone),* $(O_2N)_2C_6H_3.NH.N:CH.C_6H_3(NO_2)_2$; mw 345.25, N 24.34%. Three isomers are described in Beil **15**, 491 & [217]

*Dinitrobenzaldehyde-(2,4-dinitrophenylhydrazones),* $(O_2N)_2C_6H_3.NH.N:CH.C_6H_3(NO_2)_2$; mw 376.24, N 22.34%. Two isomers are described in Beil **15**, [217]

**2,4,6-Trinitrobenzaldehyde-(2,4-dinitrophenylhydrazone),** $(O_2N)_2C_6H_3.NH.N:CH.C_6H_2(NO_2)_3$; mw 421.25, N 23.28%. Orn-red ndls, mp 208°. Was prepd by Chattaway & Clemo(Ref 2) but the method of prepn was not described. Its expl props were not detd

*Refs*: 1)Beil **15**,[217] 2)F.D.Chattaway &

G.R.Clemo, JCS **123**,3061(1923)

**Benzaldehyde- trinitrophenylhydrazone and Derivatives**

*Benzaldehyde-(2,4,6-trinitrophenylhydrazone)*, $(O_2N)_3C_6H_2.NH.N{:}CH.C_6H_5$; mw 331.24, N 21.14%, is described in Beil **15**,495 & [222]

**Mononitrobenzaldehyde-(2,4,6-trinitrophenylhydrazones**, $(O_2N)_3C_6H_2.NH.N{:}CH.C_6H_4.NO_2$; mw 376.24, N 22.34%. Two isomers are described in Beil **15**,495

**2,6-Dinitrobenzaldehyde-(2,4,6-trinitrophenylhydrazone)** or **2,6-Dinitrobenzaldehyde-picrylhydrazone**, $(O_2N)_3C_6H_2.NH.N{:}CH.C_6H_3(NO_2)_2$; mw 421.25, N 23.28%. Yel ndls(from acet+w), mp 219-20°(dec explosively); diffc sol in alc, acet & glac AcOH; nearly insol in benz. Can be prepd from 2,6-dinitrobenzaldehyde and picrylhydrazine. Its expl props were not investigated

*Refs*: 1)Beil **15**,[222] 2)K.vonAuwers & F.Frese, Ber **58**,1372(1925)

**Peroxide Derivatives of Benzaldehydephenylhydrazone**

**Benzaldehydephenylhydrazone Peroxide**, $C_6H_5.NH.N\underset{O-O}{<}CH.C_6H_5$; mw 228.24, O 14.02%; yel ndls(from benz+petr eth); mp 65-66°(dec); defgr spontaneously; readily sol in benz, alc, eth or chlf; diffc sol in petr eth. Can be prepd by shaking benzaldehyde-phenylhydrazone in benz soln with hydrogen peroxide. The comp decomposes explosively on contact with $H_2SO_4$

*Refs*: 1)Beil **15**,(32) 2)M.Busch & W.Dietz,Ber **47**,3281(1914) & CA **9**,805-6(1915)

**3-Nitrobenzaldehyde-phenylhydrazone Peroxide**, $C_6H_5.NH.N\underset{O-O}{<}CH.C_6H_4.NO_2$; mw 273.24, O 23.42%; yel ndls(from benz), mp 83-4°(dec); very sol in eth; sol alc; diffc sol in petr eth; dec in alcoholic soln at RT and in benz at 40-50° evolves $N_2$. Can be prepd by introducing O in a benz soln of 3-nitrobenzaldehyde-phenylhydrazone(Refs 1 & 2). It is probably a mild expl

*Refs*: 1)Beil **15**,(33) 2)M.Busch & W.Dietz,Ber **47**,3287(1914) & CA **9**,806(1915)

**Benzaldehyde-phenylbenzylhydrazone Peroxide**, $C_6H_5.CH_2.N(C_6H_5).N\underset{O-O}{<}CH.C_6H_5$; mw 318.36, O 10.05%; citron-yel ndls(from benz+petr eth), mp dec ca 70-1°; readily sol in alc, eth or benz; diffc sol in petr eth. This compd very quickly turns brn when dried in air and dec in a short time. Its solns dec on warming, evolving gas(Refs 1 & 2)

*Refs*: 1)Beil **15**,(166) 2)M.Busch & W.Dietz,Ber **47**,3288(1914) & CA **9**,806(1915)

**Benzaldehyde-p-tolylhydrazone Peroxide**, $CH_3.C_6H_4.NH.N\underset{O-O}{<}CH.C_6H_5$; mw 242.27, O 13.21%; sulfur-yel ndls(from benz+petr eth), mp 77-8°(dec); readily sol in alc, eth, benz or chlf; diffc sol in petr eth. It can be prepd by shaking benzaldehyde-p-tolylhydrazone in ligroin, or better in benz soln, with a sl excess of hydrogen peroxide. This compd expl spontaneously at RT when dry. Friction or impact does not cause it to explode(Refs 1 & 2)

*Refs*: 1)Beil **15**,(155) 2)M.Busch & W.Dietz, Ber **47**,3284(1914 & CA **9**,806(1915)

**Benzaldehyde-semicarbazone and Derivatives**

*Benzaldehyde-semicarbazone*(called Kohlensäure -amid-benzalhydrazid; Benzalsemicarbazid; Benzaldehyd-semicarbazone or 1-Benzylidensemicarbazid in Ger), $C_6H_5.CH{:}N.NH.CO.NH_2$; mw 163.18, N 25.75% is described in Beil **7**, 229,(126) & [173]

*Mononitrobenzaldehydesemicarbazones*, $O_2N.C_6H_4.CH{:}N.NH.CO.NH_2$, mw 208.18, N 26.96%. Three isomers are described in Beil **7**,250,255, 261,(138,140,143) & [190,196 & 202]

*Dinitrobenzaldehyde-semicarbazones*, $(O_2N)_2.C_6H_3.CH{:}N.NH.CO.NH_2$; mw 253.18, N 27.66%. Two isomers are described in Beil **7**,265,(144) & [206]

**2,4,6-Trinitrobenzaldehyde-semicarbazone**, $(O_2N)_3C_6H_2.CH{:}N.NH.CO.NH_2$; mw 298.18, N 28.19%; lt yel plates(from AcOH); mp 214° (dec). Can be prepd from 2,4,6-trinitrobenzaldehyde in alc and the hydrochloride of semicarbazone in the presence of concd Na acetate soln. This compd turns dk-red in a warm dil NaOH soln and separates unchanged by the addn of an acid. Its expl props were not investigated

*Refs*: 1)Beil **7**,265 2)F.Sachs & H.Kantorowicz, Ber **39**,2760(1906)

**Benzaldoxine**, See Benzaldehydeoxine

**Benzalthiocarbazinic Acid Azide**. See 2-Benzylidene-thio-carbazoyl Azide

**Benzamide and Derivatives**

*Benzamide; Benzoylamide; Benzene Carbon Amide or Benzoic Acid Amide*(called Benzamid or Benzolsäure-amid in Ger), $C_6H_5.CO.NH_2$; mw 121.13,

N 11.56% is described in Beil **9**,195,(96) & [163]

*2-Azidobenzamide*, $N_3C_6H_4.CO.NH_2$; mw 162.15, N 34.56%; ndls(from w), mp 135.5-136°; sol in alc, glac AcOH, chlf, hot w, or hot benz; diffc sol in eth. Its prepn and other props are given in Refs

*Refs*: 1)Beil**9**,418 2)E.Bamberger & E.Demuth, Ber **35**,1889(1902)

**Mononitrobenzamide**, $O_2N.C_6H_4.CO.NH_2$; mw 166.13, N 16.86%. Three isomers are described in the literature: *2-Nitrobenzamide*, ndls(from dil alc), mp 174-176.6°(Ref 1); *3-Nitrobenzamide*, col ndls, mp 140-3°, bp 310-15°. This compd was prepd in 1848 by heating ammonium-3-nitrobenzoate; this reaction sometimes resulted in explosions. It can be prepd safely by a number of other methods (Ref 2); *4-Nitrobenzamide*, ndls (from w), mp 197-201.4° (Ref 3)

*Refs*: 1)Beil **9**,373,(152) & [246] 2)Beil **9**,381, (155) & [252] 3)Beil **9**,394 & [271]

**Dinitrobenzamide**, $(O_2N)_2C_6H_3.CO.NH_2$; mw 211.13, N 19.90%. Two isomers are described in the literature: *2,4-Dinitrobenzamide*, pale-greenish ndls(from hot w), mp 203-4°; prepd by heating 2,4-dinitrobenzonitrile with dil $H_2SO_4$ (Ref 1) and *3,5-Dinitrobenzamide*, lfts(from w), mp 177-183°; diffc sol in cold w, more readily sol in hot w; prepd by reacting 3,5-dinitrobenzoic acid ethyl ester or 3,5-dinitrobenzoyl chloride with $NH_3$(Ref 2)

*Refs*: 1)Beil **9**,412 2)Beil **9**,414

**2,4,6-Trinitrobenzamide**, $(O_2N)_3C_6H_2.CO.NH_2$; mw 256.13, N 21.88%; yel crysts(from acet+petr eth+benz), mp 264°(dec); prepd from 2,4,6-trinitrobenzoyl chloride and 50% $NH_3$ soln. Its expl props were not detd

*Refs*: 1)Beil **9**,418 2)P.J.Montagne,Rec **21**,382 (1902)

### Benzamidine and Derivatives

*Benzamidine* or *Benzylamidine*, $C_6H_5.C(:NH).NH_2$; mw 120.15, N 23.32%, crysts, mp ca 80°. Prepn and props in Refs

*Refs*: 1)Beil **9**,280,(129) & [199] 2)R.P.Hullin et al, JCS **1947**,395

*Benzamidine Picrate*, $C_7H_8N_2+C_6H_3N_3O_7$; mw 349.26, N 20.05%; yel ndls, mp 228-33°. Can be prepd by evaporating a chloroformic soln of an equimolecular mixt of benzamidine and picric acid

*Refs*: 1)Beil **9**,283 & [199] 2)R.P.Hullin et al, JCS **1947**,395

**Nitrobenzamidines**, $(O_2N).C_6H_4.C(:NH).NH_2$; mw 165.15, N 25.45%. Two isomers are known: *3-Nitrobenzamidine*, yel prisms(from alc), mp 89° and *4-Nitrobenzamidine*, ndls, mp 215°. Prepn & props in Refs

*Refs*: 1)Beil **9**,386,397(156,164) & [254] 2)P. Oxley et al, JCS **1946**,770-1 3)P.Oxley et al, JCS **1947**,1114 4)P.Oxley et al, JCS **1948**,308

**Nitrobenzamidine Picrates**, $(O_2N)C_6H_4.C(:NH).NH_2+C_6H_2(OH)(NO_2)_3$; mw 394.26, N 21.32%, nitro-N 14.2%. Two isomers are known: *3-Nitrobenzamidine Picrate*,yel crysts, mp 228-9° and *4-Nitrobenzamidine Picrate*, yel crysts, mp 239 -40°. These compds are probably mild expls

*Refs*: 1) Beil- not found 2)P.Oxley et al, JCS **1946**,771 3)P.Oxley et al, JCS **1947**,1114

**Dinitrobenzamidines**,$(O_2N)_2C_6H_3.C(:NH).NH_2$. One isomer, *3,5-Dinitrobenzamidine*, was isolated by Oxley et al as the picrate(see next item)

**3,5-Dinitrobenzamidine Picrate**, $(O_2N)_2C_6H_3.C(:NH).NH_2+C_6H_2(OH)(NO_2)_3$;mw 439.26, N 22.33%, nitro-N 15.94%; crysts, mp 271°. This compd is undoubtedly expl, but it was not investigated from this point of view

*Refs*: 1)Beil- not found 2)P.Oxley et al,JCS **1948**,308

### Benzamidoanisole and Derivatives

*Benzamidoanisole; Benzamiside or Methoxybenzanilide* [called Benzamino-phenol-methyläther; Benzoesäure-(o- or p)-anisid; Benz(o- or p)-anisid or Benzamino-anisol in Ger],

$C_6H_5.CO.NH.C_6H_4.O.CH_3$, mw 227.25. Two isomers are described in Beil **13**,373,469 & [174,249]

*Mononitrobenzamidoanisole*,

$O_2N.C_6H_4.CO.NH.C_6H_4.O.CH_3$; mw 272.25, N 10.29%. Three isomers are described in Beil **13**, 390,391,522 & [288]

*Benzamido-dinitroanisole*,

$C_6H_5.CO.NH.C_6H_2(NO_2)_2.O.CH_3$; mw 317.25, N 13.25%. Two isomers are described in Beil **13**,394, 526 & (188)

*Nitrobenzamido-nitroanisole*, $O_2N.C_6H_4.CO.NH.C_6H_3(NO_2).O.CH_3$; mw 317.25, N 13.25%. Three isomers are described in Beil **13**,(186,187)

*Nitrobenzamido-dinitroanisole*, $O_2N.C_6H_4.CO.NH.C_6H_2(NO_2)_2.O.CH_3$; mw 362.25, N 15.47%. Four isomers are described in Beil **13**,530 & (188,189)

*Benzamido-trinitroanisole*, $C_6H_5.CO.NH.C_6H(NO_2)_3.O.CH_3$; mw 362.25, N 15.47%. Two isomers are described in Beil **13**,(196,197)

**Nitrobenzamido-trinitroanisoles**, $O_2N.C_6H_4.CO-NH.C_6H(NO_2)_3.O.CH_3$; mw 407.25, N 17.20%. Three isomers are described in the literature: *4-(2'-Nitrobenzamido)-2,3,5-trinitro-anisole*,

ndls(from alc), mp 255°; sol in hot AcOH or alc; nearly insol in benz. Can be prepd by heating p-anisidine of 2-nitrobenzoic acid with nitric acid(d 1.52). Its expl props were not detd (Refs 1 & 2)

*4'-(3'-Nitrobenzamido)-2,3,5-trinitro-anisole*, ndls(from MNB), mp 247°; sol in hot AcOH, alc or acet; insol in benz or ligroin. Can be prepd by heating p-aniside of 3-nitrobenzoic acid with nitric acid(d 1.52) or by other methods. Its expl props were not detd (Refs 1 & 2)

*4'-(4'-Nitrobenzamido)-2,3,5-trinitro-anisole*, ndls(from 40% AcOH), mp 253°; v sol in acet; sol in $HNO_3$(d 1.4); diffc sol in alc. Can be prepd by heating the p-aniside of 4-nitrobenzoic acid with nitric acid(d 1.52). Its expl props were not detd

*Refs*: 1)Beil **13**,(196) 2)F.Reverdin,Ber **44**,2364-66(1911)

*Note*: Higher nitro derivs were not found in Beil or in CA thru 1956

**Benzamidobenzene.** See Benzanilide

**Benzamidophenol and Derivatives**

*Benzamidophenol or Benzoylaminophenol*(called Benzamino-phenol in Ger), $C_6H_5.CO.NH.C_6H_4.OH$; mw 213.23, N 6.57%. Three isomers are described in Beil **13**,372,416,469,(115,165) & [174,249]

*Mononitrobenzamidophenol*, $O_2N.C_6H_4.CO.NH.C_6H_4.OH$; mw 258.23, N 10.85%. Four isomers are described in Beil **13**,372,373 & [469]

*Benzamidomononitrophenol*, $C_6H_5.CO.NH.C_6H_3(NO_2).OH$; mw 258.23, N 10.85%. Two isomers are described in Beil **13**,390 & [195]

*Benzamidodinitrophenol*, $C_6H_5.CO.NH.C_6H_2(NO_2)_2.OH$; mw 303.23, N 13.86%. Two isomers are described in Beil **13**,396 & 528

**3,5-Dinitro-4-(3'-nitrobenzamido)-phenol**, $O_2N.C_6H_4.CO.NH.C_6H_2(NO_2)_2.OH$; mw 348.23, N 16.09%. Wh ndls(from alc), mp 215.5°. Was prepd by treating O,N-bis(3-nitrobenzoyl)-(3,5-dinitro-4-aminophenol) with cold Na hydroxide soln. It is probably a mild expl

*Refs*: 1)Beil **13**,530 2)R.Meldola & J.G.Hay,JCS **91**,1479(1907)

**5-(Benzamidotriazeno)-tetrazole.** Same as Benzoyl-tetrazolyl-isotetrazene

**Benzamiside.** Same as Benzamidoanisole

**Benzanilide and Derivatives**

*Benzanilide; Phenylbenzamide or Benzoylaniline* (called Benzasäure-anilid in Ger), $C_6H_5.NH.CO.C_6H_5$; mw 197.23, N 7.10%. is described in Beil **12**,262,(199) & [152]

**Nitrosobenzanilides**, $C_{13}H_{10}N_2O_2$; mw 226.23, N 12.38%. Two isomers are described in the literature: *2-Nitrosobenzanilide*, $C_6H_5.NH.CO.C_6H_4.NO$, col crysts(from acet), mp 171°. Its prepn and props are described in Beil **12**,267 and *N-Nitrosobenzanilide*, $C_6H_5.N(NO).CO.C_6H_5$; ndls(from eth), mp 67°(Ref 2); 75-6°(Ref 3); exp on heating; readily sol in eth; diffc sol in alc. Can be obtd by shaking benzenediazonium chloride with benzoylchloride and NaOH or by other methods

*Refs*: 1)Beil **12**,582 & [295] 2)A.Wohl,Ber **25**, 3632(1892) 3)H.von Pechmann & L.Frobenius, Ber **27**,653(1894)

*Mononitrobenzanilide*, $C_{13}H_{10}N_2O_3$; mw 242.23, N 11.57%. Three isomers are described in Beil **12**, 692,704,720,(342) : [380,391]

*Dinitrobenzanilide*, $C_{13}H_9N_3O_5$; mw 287.23, N 14.63%. Two isomers are described in Beil **12**,268 & [153]

*Benzdinitroanilide*, $(O_2N)_2C_6H_3.NH.CO.C_6H_5$; mw 287.23, N 14.63%. One isomer is described in Beil **12**,754 & [363]

*Nitrobenzonitroanilides*, $O_2N.C_6H_4.NH.CO.C_6H_4.NO_2$; mw 287.23, N 14.63%. Seven isomers are described in Beil **12**,692,704,(342,347,352) & [391] and one isomer is described by w.B.van Horssen,Rec **55**,252(1936) & CA **30**,5198-9(1936)

*Nitrobenzdinitroanilides*, $(O_2N)_2C_6H_3.NH.CO.C_6H_4.NO_2$; mw 332.23, N 16.87%. Two isomers are described in Beil **12**, 754 & 755 and one isomer is described by W.B.van Horssen,Rec **55**, 249(1936) & CA **30**,5198-9(1936)

*Dinitrobenznitroanilide*, $O_2N.C_6H_4.NH.CO.C_6H_3(NO_2)$. One isomer, the 3,5-dinitrobenz-(4'-nitro-anilide), is described by W.B.van Horssen,Rec **55**,252-3(1936) & CA **30**,5198-9(1936)

*Trinitrobenzanilide*, $C_6H_5.NH.CO.C_6H_2(NO_2)_3$; mw 332.23, N 16.87%. One isomer, the *2,4,6-trinitro-*, is described by I.Tanasescu & I.Nanu,Ber **72B**, 1092(1939) & CA **33**,5827(1939)

*Benztrinitroanilide*, $(O_2N)_3C_6H_2.NH.CO.C_6H_5$; mw 332.23, N 16.87%. One isomer, the *Benz-2',4',6'-trinitroanilide*, is described in the literature

*Refs*: 1)Beil **12** [423] 2)W.Borsche,Ber **56B**, 1940(1923) & CA **18**,533(1924) 3)N.M.Cullinane et al, JCS **1932**,2364 & CA **26**,5925-6(1932)

**Dinitrobenzdinitroanilide**, $(O_2N)_2C_6H_3.NH.CO-$

$C_6H_3(NO_2)_2$; mw 377-23, N 18.57%. The isomer *3,5-dinitrobenz-(2',4'-dinitroanilide)*, pale yel crysts(from AcOH), mp 213°; readily sol in acet & warm AcOH; diffc sol in alc or benz; insol in petr eth or chlf, can be prepd by nitration of 3,-5-dinitrobenzanilide with abs nitric acid at -15°. Its expl props were not detd

*Refs*: 1)Beil- not found 2)W.B.van Horssen,Rec **55**,251(1936) & CA **30**,5198-9(1936)

**Benzanilide-Diazonium Derivatives**

**1-Benzanilide-4-diazoniumhydroxide or** *Benzamino-benzene-4-diazoniumhydroxide* [called 1-Benz-amino-benzoldiazoniumhydroxyd-(4) or *N*-Benzoyl -anilin-diazoniumhydroxyd-(4) in Ger], $C_6H_5.CO-NH.C_6H_4.N(:N).OH$; mw 241.24, N 17.42%. This compd is known only in the form of its salts, some of which are expl, such as: *Chloride*, $C_6H_5.CO-NH.C_6H_4.N_2.Cl$, col crysts, mp- dec ca 139°; readily sol in w or alc; insol in eth. It can be obtd by treating N-benzoyl-p-phenylenediamine hydrochloride with amyl nitrite in AcOH soln and pptg the salt with eth; *Perchlorate*, $C_6H_5.CO-NH.C_6H_4.N_2.ClO_4$, col crysts(from w) which turn yel on exposure to light; mp expl on heating. It can be prepd by treating the chloride with $KClO_4$ in warm aq soln and cooling the mixt to ppt the perchlorate. This compd also expl on impact or percussion

Other salts, such as the nitrite, acetate, carbonate, theocyanate, picrate, etc, many of which dec on heating, were also prepd and described by Morgan et al(Refs 1, 2 & 3)

*Refs*: 1)Beil **16**,604 2)G.T.Morgan & F.M.Micklewait,JCS **87**,933(1905) 3)G.T.Morgan & M.Alcock, JCS **95**,1323(1909)

**1-Benzanilide-3-nitro-4-diazoniumchloride** [called 3-Nitro-1-benzamino-benzol-diazoniumchlorid-(4) or N-Benzoyl-3-nitro-anilin-diazoniumchlorid in Ger], $C_6H_5.CO.NH.C_6H_3(NO_2).(:N).Cl$; mw 304.69, N 18.39%; yel-wh lfts of the dihydrate, mp expl mildly on heating. It was prepd by diazotizing $N^4$-benzoyl-2-nitro-1,4-phenylenediamine with $NaNO_2$ + HCl (Refs 1 & 2)

*Refs*: 1)Beil **16**,608 2)C.Bülow & E.Mann,Ber **30**,984(1897)

**Benzazide.** See Benzoyl Azide under Benzoic Acid

**Benzazimidol or Benzohydroxytriazole.** See under Benzotriazole and Derivatives

## BENZENE AND DERIVATIVES

**Benzene,** *Benzole, Phenylhydride, Cyclohexatriene, Phene* (called Benzol in Ger) ; mw 78.11, N 7.74%; col, vol, flam liq; mp 5.5°, bp 80.1°, fl p 12°F, d 0.8794 at 20°; $Q_c^p$ at 25° ($H_2O$ liq) 789 kcal/mol; vap press 100mm at 26.1°; sl sol in w(0.6% at 20°); miscl in all propns with alc, eth, acet or glac AcOH; sol in most org solvs. The vapors of benz are extremely toxic and exposure may induce acute or chronic poisoning. The max allowable concn for 8 hr exposure is 35ppm in air or 112g/m³. Its volatility and flammability make it a potential fire hazard, so great care must be exercized in its handling and transportation. Air contg more than 1.3% benz will propagate a flame; 1.4 to 8% in air(by vol) is an expl mixt(Refs 4 & 8)

Benz(crude) is obtd comly by fractnl distn of light oil, which in turn is formed as a by-product in the high temp destructuve distn of coal; it is obtd from coke oven gas, carburated water gas, and by the cracking of gasoline under press and elevtd temp(Ref 7)

Benz is the parent compd of a series of aromatic hydrocarbons from which many of the most import expls are derived. Benz is an excellent solv from which many expl intermediates can be prepd. Its di-, tri-, and tetra- nitrocompds are expls

*Refs*: 1)Beil **5**,179,(95) & [119] 2)Thorpe **1** (1937),667-75 3)USBurMinesBull **279**,78(1939) 4)MfgChemAssocn,"Safety Data Sheet SD-2"(1946) 5)Kirk & Othmer **2**(1948),420-42 6)T.E.Jordan, "Vapor Pressure of Organic Compounds", Interscience, NY(1954),Chapt 1,p 19 7)Faith,Keyes & Clark(1957),138-46 8)Sax(1957),342-4

**Benzene, Analytical Procedures.** Benzene can be detected by conversion to m-dinitrobenzene(using for nitration equal vols of fuming nitric acid and concd sulfuric acid) and subsequent identification of the latter compd(Refs 3 & 9).

A Brit test for detection of benz in air involves the absorption of the vapor in concd sulfuric acid contg formaldehyde; an orange-brown color is produced even with traces of benz(Ref 9,p 525). Elkins(Ref 10,p 283) describes the socalled pernitrite test, which consists of adding to a small sample 2ml of aq Na nitrite soln & 2ml 2N sulfuric acid, shaking, adding 2ml 3% hydrogen sulfide and shaking again. After waiting 1min, apellet of KOH is added and if benz is present a red -brn coloration forms around the pellet

For the quantitative detn of benz many methods

have been proposed. One of the most accurate methods is the Smyth modification of the m-dinitrobenzene-reduction method, using titanous chloride soln. This method is described in detail by Jacobs (Ref 9,p 531-6) and briefly described here under Dinitrobenzene. A more rapid but less accurate method is the m-dinitrobenzene-butanone method described in Refs 4 & 5 and in Ref 9,pp 527-29. Its modifi cations are described in Ref 9,pp 529-31 (See also Ref 7). Still another but less accurate method, which is simple and may be performed in the field, is the oxidation method in the presence of hydrogen peroxide and iron salts. This method is described by Cook & Kicklen(Ref 2) and by Jacobs(Ref 9,pp 537-9)

According to Elkins(Ref 10,p 283), the amt of benz can be estimated approx from the refractive index of the fraction of distillate contg benz. The method is applicable if only hydrocarbons are present

A microcolorimetric method for detn of benz in air is described by Elkins(Ref 10,pp 284-6) (see also Ref 8). Detn of benz in urine is described in Ref 10,p 369

*Refs*: 1)Beil **5**, 196,(106-7) & [145-6] 2)W.A.Cook & J.B.Ficklen, IEC,AnalEd **4**, 406(1932) 3)W.P. Yant et al, USBurMinesReptInvest RI **3282**(1935) 4)H.H.Schrenck et al, USBurMinesRI **3287**(1935) 5)S.J.Pearce et al, USBurMinesRI **3302**(1936) 6)W.P.Yant et al, USBurMinesRI **3323**(1936) 7)R.H. Dolin,IEC,AnalEd **15**,242(1943) 8)H.D.Baernstein, IEC,AnalEd **15**,251(1943) (Photometric determination of benzene, toluene and their nitro derivatives) 9)Jacobs(2949),524-39 10)Elkins(1950), 282-6 & 369

**Azido and Azidonitro Derivatives of Benzene**

**Azidobenzene**(called Azidobenzol, Triazobenzol, Phenylazid or Diazobenzolimid in Ger), $C_6H_5.N_3$; mw 119.12, N 35.28%; pale yel oil with odor like bitter almond; mp expl on distn at normal press; thermochem props(Ref 5); sl sol in alc or eth; insol in w. Many methods of prepn are listed in Ref 1. Treatment with $AlCl_3$, in absence of solv, results in an expln(Ref 4)

*Refs*: 1)Beil **5**, 276,(141) & [207] 2)O.Turek, Chim & Ind(Paris), **Special No**, 833-7(June 1933) & CA **28**,750(1934) 3)R.O.Lindsay & C.F.H.Allen, Org Synth **22**, 96-8(1942) & CA **36**, 579(1942); Org-Synth Coll Vol **3**, 710-11(1955) 4)W.Borsche & H.Hahn, Chem Ber **82**, 260-3(1949) & CA **44**,1101 (1950) 5)P.Gray & T.C.Waddington, PrRoySoc **235A**, 481(1956) & CA **50**, 15203(1956)

**Diazidobenzene**, $N_3.C_6H_4.N_3$; mw 160.14, N 52.48%. Two isomers are described in the literature: *1,3-Diazidobenzene*, yel ndls, mp 5°, dec on steam bath; dec in concd $H_2SO_4$ with the appearance of flame and a sl deton. It was prepd by treating a soln of m-phenylenediamine in 50% $H_2SO_4$ with $NaN_3$ and diazotizing with $NaN_2$(Refs 1 & 4). Kleinfeller(Ref 5) reported that the action of m-$C_6H_4(N_3)_2$ upon BrMgC:C-MgBr gave an amor yel compd, $C_8H_6N_6$, which exploded on heating and *1,4-Diazidobenzene*, lt yel tablets(from eth), mp 83°, expl extremely violently on heating; readily dec by heating on steam bath; readily sol in eth or chlf; diffc sol in alc; insol in w. It was prepd from p-amino-azidobenzene by diazotization, conversion to the diazoperbromide and thence to the diazido comp(Refs 2 & 3). Also see Ref 6

*Refs*: 1)Beil **5**,279 & [209] 2)Beil **5**,279 3)O.Silberrad & B.J.Smart,JCS **891**,171(1906) 4)M.O.Forster & H.E.Fierz,JCS **91** II,1953(1907) 5)H.Kleinfeller,,JPraktChem **119**,61-73(1928) & CA **22**,2566(1928) 6)S.Maffei & L.Coda,Gazz **85**, 1300-3(1955) & CA **50**,9330(1956)

**Azidomononitrobenzene**, $O_2N.C_6H_4.N_3$; mw 164.12, N 34.14%. Three isomers (all explosive) are described in the literature: *1-Azido-2-nitrobenzene*, yel ndls(from benz+alc); mp 51-3°; readily sol in alc, glac AcOH or benz; sol in eth. Its prepn is given in Refs 1 3 & 4); *1-Azido-2-nitrobenzene*, col ndls(from dil alc), mp 52-5°, dec by heating on steam bath; readily sol in alc, eth, benz, or $CS_2$, insol in w. Its prepn is given in Ref 1; *1-Azido-4-nitro-benzene*, col lfts(from dil alc), mp 71-4°, dec by heating on steam bath; v readily sol in hot alc, eth, benz, glac AcOH or C disulfide; diffc sol in cold w. Its prepn is given in Ref 2

*Refs*: 1)Beil **5**,278 2)Beil **5**,278,(143) & [209] 3)P.A.S.Smith & J.H.Boyer, Org Synth **31**, 14-16 (1951) 4)S.Maffei & L.Coda,Gazz **85**,1300-3 (1955) & CA **50**,9330(1956)

**Azidodinitrobenzene**, $(O_2N)_2C_6H_3.N_3$, mw 209.12, N 33.49%. Only the *1-Azido-2,4-dinitro-benzene* is described in the literature; lt yel, almost col ndls(from dil AcOH), mp 57-8° & 65-9°,explodes on heating rapidly; readily sol in most solvs; insol in w. Its prepn and other props are given in Refs 1 & 2

McNutt(Ref 3) used the *Pb salt* with $Ba(NO_3)_2$ as a priming compon mixt, and instead of the Pb salt, he proposed alk & alkaline earth salts of azidodinitrobenzene with LA, $Ba(NO_3)_2$, $Sb_2S_3$,

Pb sulfocyanate & ground glass as priming compns (Ref 6). McNutt(Ref 4) also prepd priming mixts contg the *Pb salt & Ag tetracene*, and azidodinitrobenzene with basic LSt and other ingredients such as BaK nitrate double salt, $Sb_2S_3$, Ca sililicide & ground glass(Ref 5). Kelson(Ref 7) patented the use of the *K salt* as an ingredient of priming compns in conjuction with MF, Pb hypophosphite, $K_2Ba(NO_3)_4$ & $Sb_2S_3$

*Refs*: 1)Beil **5**,279 & [209] 2)G.Powell,JACS **51**,2438(1929) 3)J.McNutt,USP 1906394(1933) & CA **27**,3612(1933) 4)J.D.McNutt,USP 1930653 (1933) & CA **28**, 328(1934) 5)J.D.McNutt,USP 2002960(1935) & CA **29**,4944(1935) 6)J.D.McNutt, USP 2005197(1935) & CA **29**,5274(1935); BritP 432096(1935) & CA **30**,618(1936) 7)V.J.Kelson, Australian P104189(1938) & CA **32**, 8782(1938)

**1-Azido-2,4,6-trinitro-benzene or Picrylazide** (called 2.4.6-Trinitro-diazobenzolimid or Pikrylazid in Ger), $(O_2N)_3C_6H_2.N_3$, mw 254.12, N 33.07%; yel prisms(from abs alc), mp 89-93° (dec); sol in alc, benz, or chlf; insol in ligroin or petr eth. One method of prepn is by reacting equi-molar quants of picryl chloride with $NaN_3$ in aq alc soln. Other methods of prepn and props are given in Refs 1, 2, 3 & 4

This compound is more sensitive to impact than tetryl; it detonates on sl impact. It is an expl more powerful and brisant than TNT(power 139% & brisance 132% TNT). It is unstable and loses N when heated

*Refs*: 1)Beil **5**,279,(144) & [209] 2)E.Schrader, Ber **50**, 777(1917) 3)H.Rathsburg, GerP 341961 (1921) 4)A.Korczynski & St.Namyslowski, Bull Fr **35**, 1186-94(1924) & CA **19**,644(1925)

**1,3(or 4,6)-Diazido-4,6(or 1,3)-dinitro-benzene,** $(O_2N)_2C_6H_2(N_3)_2$, mw 250.14, N 44.80%. Yel pltlts, mp 78°; expl violently when heated above the mp. Was prepd by treating dinitrodichlorobenzene with Na azide in mixt of acetone, alc & w (Ref 3)

McNutt (Ref 2) considered a mixt of diazidodinitrobenzene and tetracene with $Ba(NO_3)_2$, $Sb_2S_3$, $PbO_2$ & ground glass as a suitable priming mixt for small arms

*Refs*: 1)Beil- not found 2)J.D.McNutt,USP 2009556(1935) & CA **29**,6429-30(1935) 3)R.J. Gaughran et al, JACS **76**, 2235(1954) & CA **49**, 6238(1955)

**1,3-Diazido-2,4,6-trinitro-benzene or Picryldiazide,** $(O_2N)_3C_6H(N_3)_2$, mw 295.14, N 42.72%, OB to $CO_2$ -35.2%; yel crysts, mp 92°. Was prepd by heating a soln of picryl dichloride with Na azide. It is an extremely sensitive expl

*Refs*: 1)Beil- not found 2)Blatt,OSRD **2014**(1944), listed under Nitro Compounds

**1,3,5-Triazido-2,4-dinitro-benzene,** $(O_2N)_2C_6H(N_3)_3$, mw 291.16, N 52.93%, OB to $CO_2$ -46.7%. Crysts(from alc), mp 116-7°(dec); compd turns brn at 50° and becomes semi-liq; insol in w; sol in acet or boiling alc, sl sol in cold alc. A comp prepd by Friederich and called "dinitrotriazidobenzene", without identifying the position of the groups, was probably the same as the 1,3,5-triazido-2,4-dinitro-benzene which was later prepd by Turek(Ref 3) by refluxing dinitro-dichloro- or tribromo-benzene in aq acetone with alc Na azide. Friederich(Ref 2) proposed the use of his compd as an expl chge alone or with other ingredients in percussion caps, detonators, etc

*Refs*: 1)Beil- not found 2)W.Friederich,GerP 531253(1931) & CA **25**,5565(1931) 3)O.Turek, Chim&Ind **Special No**, pp 883-7(1933) & CA **28**, 750(1934)

**1,3,5-TRIAZIDO-2,4,6-TRINITRO-BENZENE or 2,4,6-Trinitro-1,3,5-triazido-benzene** (abbr as TATNB or TNTAB), $(O_2N)_3C_6(N_3)_3$; mw 336.16, N 50.00%, OB to $CO_2$ -28.6%. Grn-yel crysts, mp 131° (dec with formn of hexanitrobenzene); crystal d 1.805; pressed d at 42000psi 1.75, at 3000kg/cm² 1.7509 and at 5000kg/cm² 1.7526 (Ref 6a); $Q_c^v$ 840 kcal/mol(Ref 4b); 2554cal/g(Ref 8); readily sol in acet; mod sol in chlf; sl sol in alc and insol in w. It is non-hygroscopic and does not attack iron, steel, copper or brass. On exposure to light, its color deepens. No change took place in 3 years storage of TNTAB under water(Ref 6a)

It was first prepd in 1923 by Turek on treating 2,4,6-trichloro-1,3,5-trinitrobenzene with an alkali azide in alc, acet or w soln. It can be obtained also from aniline by chlorination to sym-trichloroaniline, followed by diazotization, treatment with alc to give sym-trichlorobenzene, nitration with mixed nitric-sulfuric acid to trinitrotrichlorobenzene and finally treatment with an alc soln of Na azide(Refs 3,5,6a & 8)

**Properties of TATNB.** When ignited in the open, it burns rapidly with a dazzling blue flame. When dead-pressed(ca 3000kg/cm²), it either burns when ignited or puffs weakly(Ref 6a). When confined(even slightly, as in detonators) it expl when heated in a flame. A violent deton takes place when TATNB, compressed in a metal tube, is heated

*Behavior Toward Metals* was detd by Ficheroulle

& Kovache(Ref 6c,p 15); *Burning Rate* 0.65cm/sec (Ref 6b); *DeadPressed* ca 42000 psi, d 1.75(Ref 8); *Brisance by Plate Punching Test* is ca 158% TNT(Ref 6a); *Explosion Temperature* 150°(10secs) (Ref 8); *Figure of Insensitiveness(FI).* See under Impact Sensitiveness; *Friction Sensitiveness.* Although reported in some literature as "relatively insensitive", it is not always true as the experience at PicArsn has shown. When a cryst sample of TATNB was carefully diminuted to 50-100(US Std Sieve) in a flat agate mortar using a very small portion at a time(ca 0.2g), one of the portions vigorously detonated with evoln of flame. No detons took place when a hardwood mortar and pestle were substituted; *Hygroscopicity:* practically non-hygroscopic(Refs 6a,6c & 8); *Ignitability of Compressed Pellets* was studied by Schmitt(Ref 6); *Impact Sensitiveness:*FI 6%PA; Wöhler Apparatus 60% positive at 30cm vs 7.5cm for MF; BurMines App, 2kg wt 25cm(Refs 6a & 8) (see also Ref 6c); *Initiating Action:* 1.0g of commercial TNT compressed at 500kg/cm$^2$ required 0.02g TATNB(compressed at 300kg/cm$^2$) for complete deton, while only 0.01g is required to deton 1.0g of Tetryl(Ref 6a); *Power by Trauzl Test:* 179% TNT at d 1.0; 152%PA and 90%PETN (Ref 6a); *Sand Test Value-* not found; *Solubility* in various solvents was detd by Ficheroulle & Kovache(Ref 6c,p 15); *Thermal Decomposition* was studied by Turek(Ref 4) and then by Yoffe (Ref 7); *Thermal Stability.* It is fairly stable at below the mp, but when melted it is converted to hexanitrosobenzene; *Uses:* Turek(Ref 2) patented the use of TATNB as a primary expl. It can be press-loaded at ca 3000kg/cm$^2$(Ref 6a). SFM-CTG, FrP 893941(1944) & CA **47**, 8374, patented its use as a component of priming compns Ficheroulle & Kovache (Ref 6c) examined its props for use in priming compns

*Refs:* 1)Beil- not found 2)O.Turek,BritP 298629 and 298981(1927) & CA **23**, 3101(1929); GerP 498050(1927) & GerP 494289(1928), CA **24**,2886 & 3904(1930) 3)O.Turek,Chim&Ind(Paris) **26**,781 (125T)(1931) & CA **26**,848(1932);PicArsn Translation No 70 by H.Voos(1960); Chim & Ind **29**,883 (1933) 4)O.Turek, Chim & Ind **Special No**,pp 883-7(1933) & CA **28**,750(1934) 4a)Stettbacher(1933), 329 4b)A.Schmidt,SS **29**,263(1934) 5)Davis(1943), 436 6)R.Schmitt,SS **38**,133(1943) & CA **38**,2822-3 (1944) 6a)Blatt,OSRD **2014**(1944) 6b)A.F.Belyaev & A.E. Belyaeva,DoklAkadN **52**,503(1946) & **56**,491(1947); CA **41**,4310(1947) & **44**,8109(1950) 6c)H.Ficheroulle & A.Kovache,MP **31**,15-16 & 26 (1949) & CA **46**,11687(1952) 7)A.D.Yoffe,PrRoySoc **208A**,188(1951) & CA **46**,5845(1952) 7a)Stettbacher,Pólvoras (1952) 8)PATR **1740**,Rev 1(1958), 340-3, & OrdCorpsPamphlet ORDP 20-177(1960), 283-5

**Azido-Halogen Derivatives of Benzene**

**Azidoiodosobenzene,** $N_3.C_6H_4.IO$; mw 261.02, N 16.10%. Three isomers are described in the literature: *1-Azido-2-iodoso-benzene*, softens ca 85°, mp 90-100°(dec)(Ref 1) *1-Azido-3-iodosobenzene*, yel amor mass, mp-expl ca 125° and its *Formate*, expl ca 78°(Ref 2); and *1-Azido-4-iodosobenzene*, expl on heating to 130° or on contact with concd $HNO_3$ or concd $H_2SO_4$; its *Chromate*, a dk-red mass, expl by friction or heating to 71°; and its *Formate*, expl ca 85°(Ref 2). The prepn and other props of these iodoso-azido compds are given in the Refs

*Refs:* 1)Beil **5**,(142) 2)Beil **5**,(143) 3)M.D.Forster & J.H.Schaeppi,JCS **101** II,1362-3(1912)

**Azidoiodoxybenzene,** $N_3.C_6H_4.IO_2$; mw 277.02, N 15.17%. Three isomers are described in the literature: *1-Azido-2-iodoxy-benzene*, brownish ndls(from glac AcOH), expl violently by friction or on heating to 157°(Ref 1); *1-Azido-3-iodoxy-benzene*, brownish ndls(from w or glac AcOH); expl ca 175-80°(Ref 2) and *1-Azido-4-iodoxy-benzene*, crysts which rapidly become brown, expl ca 170° or on contact with concd $H_2SO_4$(Ref 2)

*Ref:* 1)Beil **5**,(142) 2)Beil **5**,(143) 3)M.O. Forster & J.H.Schaeppi,JCS **101** II, 1365(1912)

**1-Azido-2,4-dichloro-benzene,** $N_3.C_6H_3Cl_2$; mw 188.02, N 22.35%; yellowish ndls(from alc) or prisms(from acet or benz), mp 51-4°(dec at 160° on prolonged heating); sol in alc, benz, eth, chlf or petr eth; insol in w. This compd expl on rapid heating or by strong impact, generating much smoke, and when completely dry, it expl on heating below its mp. The prepn and other props are given in Beil **5**, [208]

**Nitroso and Nitronitroso Derivatives of Benzene**

*Nitrosobenzene,* $C_6H_5.NO$; mw 107.11, N 13.08%; col crysts(from alc+eth), mp 67.5-8° to an emerald-grn liq; readily sol in nearly all solvs with the solns immedy turning an emerald-grn color. Many methods are known for the prepn of nitrosobenzene but the principal ones are by the oxidn of the amine and of the N-substituted hydroxylamine. Various other props and chemical reactions of nitrosobenzene are described in Beil **5**,230,(123) & [169]

**Dinitrosobenzene,** $C_6H_4(NO)_2$; mw 136.11, N

20.58%. Two isomers are described in the literature: *1,3-Dinitrosobenzene*, yel crysts(from alc+eth), mp 146.5°; readily sol in alc, benz or hot glac AcOH; mod sol in ligroin; diffc sol in eth; insol in w. The melted mass and the solns are colored grn(Ref 1)
*1,4-Dinitrosobenzene*, dk-yel, mp- at 184° begins to turn brn and at 245°, compd is completely darkened; dec at temp of steam bath; diffc sol in most org solvs(Ref 2). The prepn of the dinitroso compds is given in the Refs
*Refs*: 1)Beil **5**, 232 2)Beil **5**,[171]

**Hexanitrosobenzene**, ON.C-C(NO)=C.NO ; mw
ON.C-C(NO)=C.NO
252.14, N 33.35%; crysts, mp 195°; was claimed to be obtd by Turek(Ref 2) when sym-trinitrotriazidobenzene(qv) was heated above 131° in xylene. According to Blatt(Ref 3), this compd has an Impact Sensitiveness,FI, 26%PA; a Lead Block Expansion value 178%PA, and, although not a primary expl, it is equal to Tetryl as a booster. This compd is not listed in CA indices
*Refs*: 1)Beil- not found 2)O.Turek,Chim&Ind (Paris) **26**,785(129T)(footnote)(1931) &CA **26**, 848(1932) 3)Blatt,OSRD **2014**(1944)

**Mononitronitrosobenzene**, $O_2N.C_6H_4.NO$; mw 152.11, N 18.42%. Three isomers are described in the literature: *2-Nitro-1-nitrosobenzene*, yel -wh crysts(from et acet or acet), mp 126-126.5°, turns grn at ca 120°; readily sol in hot chlf,hot benz or hot acet; mod sol in hot alc or hot ligroin; diffc sol in eth and nearly insol in petr eth or w. The solns are colored intensively grn(Ref 1); *3-Nitro-1-nitrosobenzene*, col ndls, mp 89.5-91° to a grn liq; readily sol in hot alc, chlf, acet or glac AcOH; diffc sol in eth; almost insol in petr eth(Ref 2); *4-Nitro-1-nitrosobenzene*, lt yel ndls (from alc), mp 118-9-119° to a grn liq; readily sol with a grn color in benz, chlf, glac AcOH, acet or hot alc; mod sol in ligroin; diffc sol in eth; nearly insol in w(Ref 3). The mononitronitrosobenzenes are volat at the temp of a steam bath. Their prepn is given in the Refs
*Refs*: 1)Beil **5**,256 2)Beil **5**,257 & [192] 3)Beil **5**,257 & [192-3]

**2,4-Dinitro-1-nitrosobenzene**, $(O_2N)_2C_6H_3.NO$; mw 197.11, N 21.32%; dk-yel ndls(from glac AcOH), mp 133° to a dk-grn liq; sol in warm alc, glac AcOH or benz with a grn-colored soln; dec in warm NaOH soln. Can be prepd by treating β-[2,4-dinitrophenyl] - hydroxylamine with cold chromic acetate(Refs 1 & 3)

Friederich(Ref 2) patented the use of the *Basic Pb salt* of dinitronitrosobenzene as a component of primary compns
*Refs*: 1)Beil **5**, [202] 2)W.Friederich,BritP 192830(1921) & JSCI **42**,332A(1923) 3)W.Borsche, Ber **56**,1498(1923)

**2,4,6-Trinitro-1-nitrosobenzene**, $(O_2N)_3C_6H_2.NO$; mw 242.11, N 23.14%; grn-yel lfts(from glac AcOH), mp 198°; dec on contact with concd $HNO_3$. Can be prepd by oxidn of 2,4,6-trinitrophenyl hydroxylamine with Cr trioxide in AcOH soln (Refs 1 & 2). Its expl props were not investigated
*Refs*: 1)Beil **5**,276 2)R.Nietzki & R.Dietschy, Ber **34**,59(1901)

**Dinitrodinitrosobenzene**, $(O_2N)_2C_6H_2(NO)_2$; mw 226.11, N 24.78%. The *4,6-Dinitro-1-2-dinitrosobenzene* is the only isomer described in the literature: crysts(from alc), mp 172°, dec by exposure to light. This compd appears to have been first prepd by Rathsburg(Ref 3) and later by Korczyński & Namyslowski(Ref 4) by heating picryl chloride in alc at 100° with aq $NaN_3$. Rathsburg(Ref 3) called this compd *1,3-dinitro-4,5-dinitrosobenzene* and prepd its *K, Na* and *Pb salts* which were proposed for use in detonators. Mixts suitable as a top(primary) chge in detonators consisted of the *K salt of dinitrodinitrosobenzene* and the diffc sol salts of hydrazoic acid, tetrazole derivs, etc(Ref 2). Boyer & Schoen(Ref 6) studied the reduction and other reactions of this compd which they called 1,5-dinitro-2,3-dinitrosobenzene. Blatt(Ref 5) lists this compd as *1,3-dinitro-4,5-dinitrosobenzene*
*Refs*: 1)Beil- not found 2)H.Rathsburg,BritP 177744(1921); CA **16**,3399(1922) & JSCI **41**,441A (1922) 3)H.Rathsburg,BritP 190844(1921); CA **17**,2960(1923) &JSCI **42**,332A(1923) 4)A. Korczyński & St.Namyslowski,BullFr **35**,1186 -94(1924) & CA **19**,644(1925) 5)Blatt,OSRD **2014**(1944) 6)J.H.Boyer & W.Schoen, JACS **78**, 423-5(1956) & CA **50**,13017(1956)
*Note*: Compare with info on Dinitrobenzofuroxan under Benzofuroxan and Derivatives

### Nitro-Derivatives of Benzene

**Mononitrobenzene(MNB)** or **Oil of Mirbane**(called Nitrobenzol or Mirbanöl in Ger), $C_6H_5.NO_2$; mw 123.11, N 11.38%; lt yel oil, mp 5.6-5.7°, bp 210° -9°, vap press 0.262 mm Hg at 20°(Ref 10), d 1.205 at 18°; $Q_C^P$ 740kcal/mol(Ref 3) or 6033 cal/g(Ref 5); readily sol in alc, eth or benz; sl sol in w(0.19% at 20°). MNB is toxic and its MAC in air is 1ppm or 5mg per $m^3$ of air(Ref 11). It represents a moderate expln hazard when exposed to heat or flame(Ref 11). Its thermal decompn was studied by Condit & Haynor(Ref 8)

MNB was first prepd in 1827 by Mitscherlich on treating benz with fuming nitric acid. A better way is to nitrate benz with mixed nitric-sulfuric acid(Refs 1 & 4). Details of a lab procedure are given by Davis(Ref 7)

The expl value of MNB is very low but when mixed with oxidizing agents, such as nitric acid or nitrogen peroxide, it produces very powerful expls(see Sprengel Explosives, Helhofite, etc). It has been reported(Ref 9) that Al chloride added to MNB contg 5% phenol caused such a rise in temp that the mixt exploded. During WWI some airplane bombs contd two compartments separated by a thin partition; one compartment contd MNB and the second contd liq nitrogen peroxide. On impact with the ground the partition broke and the two liqs mixed, forming an extremely powerful expl which was detonated by a fuze. As early as 1881, Turpin proposed a shell using MNT & liq $N_2O_4$ in separate comartments(Ref 3a).During WWII, Roth(Ref 6) in Germany, proposed a mixt of equal proprns of MNB, NG & TeNMe. This mixt possessed 117% the power of NG, according to Trauzl Test results. Another mixt, consisting of 22.5 MNB and 77.5% TeNMe, had the following characteristics: *d* 1.68, *Power*- 117%NG or about equal to PETN, *Sensitivity to Impact*- same as for NG, and *Vel of Deton*- (max) 7700m/sec at d 1.68(Ref 6)

Peters(Ref 2) patented a blasting expl consisting of MNB 4, AN 75, nitrated potato meal 20 & asphalt 1% (See also Anilithe Vol I,pA442-R)

*Refs*: 1)Beil **5**,233,(124) & [171] 2)G.M.Peters, USP 1048578(1912) & CA **7**,703(1913) 2a)Marshall I(1917),253 2b)Colver(1918),117-137 3)W.E.Garner & C.L.Abernethy,PrRoySoc **99A**, 213-35(1921) & CA **15**,3748(1921) 3a)Marshall **3** (1932), 51, 71, 99 & 176 4)Stettbacher(1933), 255-6 5)A.Schmidt,SS **29**,262(1934) & CA **29**, 3841(1935) 6)J.F.Roth,SS **36**,4, 28 & 52(1941) & CA **35**,5317(1941) 7)Davis(1943),133 8)P.C. Condit & R.L.Haynor,IEC **41**,1700-4(1949) & CA **43**,9045(1949) 9)Anon,C&EN **31**,4915(1953) & CA **48**,1684(1954) 10)T.E.Jordan,"Vapor Pressure of Organic Compounds", Interscience,NY (1954),Chapt 7,pp181 & 194 11)Sax(1957),944 12)E.Leclerc & F.Devlaminck,BullCentreBelge-ÉtudeDocEaux(Liège), No **14**,246(1951/IV) (Toxicity of MNB and DNB's found in the waste waters of expl plants)

**DINITROBENZENE** (DNB)(Called Dinitrobenzol in Ger) $C_6H_4(NO_2)_2$; mw 168.11, N 16.67%, OB to $CO_2$ -95.2%. Three isomers, o-(or 1,2-), m-(or 1,3-) and p-(or 1,4-), can be obtd on nitration of MNB but in accordance with the Crum-Brown-Gibson rule the substitution of the second $NO_2$ group takes place chiefly in the meta position; hence only small quants of the ortho and para DNB are found in the coml product:

**Ortho- or 1,2-Dinitrobenzene (1,2-DNB)**, col monocl prisms, ndls(from w or AcOH), tablets (from alc, benz or chlf); mp 117-8°, expl when heated in a test tube to 472°, bp 319° at 774mm Hg, d 1.59 at 18°, $Q_c^p$ 703kcal/mol(Ref 7) or $Q_c^v$ 4194cal/g(Ref 14); very sol in chlf or et acet; sol in benz(5.7% at 18°); sl sol in alc(1.9% at 21°), and diffc sol in w(0.01% in cold w). This compd can be steam distd. 1,2-DNB appears to have been known since ca 1874 and can be prepd by nitration of benzene(or MNB) or by the reaction of o-nitroaniline nitrate with Cu sulfate and Na nitrate. Other methods of prepn are given in Ref 1. Ortho-DNB is usually present in coml DNB but the principle constituent is 1,3- or meta -DNB. For toxicity see Ref 29

**Meta- or 1,3-Dinitrobenzene (1,3-DNB)**; col rhmb crysts, mp 88-91°, expl when heated to 580°, bp 302° at 770.5mm Hg, vap press 1.1mm Hg at 110° (Ref 27), d 1.57 at 20°, $Q_c^p$ 699.8kcal/mol(Ref 7) or $Q_c^v$ 4155cal/g(Refs 11 & 14); sol in benz(39.5% at 18°) or in abs alc(3.3% at 20°); sl sol in cold w, chlf or et acet; can be steam-distd. According to Colver(1918),p 18, it was first prepd in 1834 by Mitscherlich, but the earliest Ref in Beil **5**, 528, is the paper of Deville(ca 1840). Meta-DNB can be prepd by nitration with mixed nitric-sulfuric acid of either MNB or benz. Details of prepn are given by Stettbacher(Ref 12) and the lab prepn by Davis(Ref 21). Other methods of prepn and props are described in Refs 2,6,15 & 16. A comprehensive description of numerous additive products of 1,3-DNB is reported by Karvé & Sudborough (Ref 8) and by Khaishbashev & Gromova (Ref 26). The *hydroxylamine Na methylate salt*, $C_6H_8O_6N_4Na_2$, lt red crysts, expl mildly on heating or on contact with w (Ref 40,p 2537)

**Para- or 1,4-Dinitrobenzene (1,4-DNB)**, col monoclinic prisms, ndls(from alc), mp 173.5-174°; can be heated in a closed test tube to 360° without decompn; bp 299° at 777mm Hg, vap press 1.6mm Hg at 110°(Ref 27), d 1.625 at 18°, $Q_c^p$ 692.9kcal/mol(Ref 25) or $Q_c^v$ 4146cal/g(Ref 14); sol in eth; sl sol in w or alc; can be steam distilled. Para -DNB appears to have been known since 1874 (Rinne & Zincke), when it was obtd in small quants by nitration of benz. It can be prepd in

75% yield from p-nitroaniline, Amm persulfate and $H_2SO_4$ in the presence of $AgNO_3$. Other methods of prepn are given in Refs 3 & 20. Para -DNB is present in small quants in coml DNB. The *Na salt*, $C_6H_4O_4N_2Na_2$, red crysts, deton mildly when heated(Ref 4a,p 2529)

**DNB, Commercial**, yel oil, mp ca 85°, consists of about 93.5% m-DNB, 6.4% o-DNB and 0.1% p-DNB(Ref 15). A method of separating isomeric DNB's to obtain pure m-DNB has been patented by Coward(Ref 17). DNB is a HE which is extremely toxic having an effect similar to that of TNT. It is absorbed thru the lungs and digestive tract and may effect vision heart action and nervous reflexes(Refs 9,15 & 23). Several cases of intoxication in ammo plants from exposure to DNB causing methemoglobinemia have been reported(Ref 24). Because of its toxicity, the use of DNB was forbidden in France (Ref 15) and it was replaced in expl compns by DNT. The toxicity of DNB has also been examined and described by other investigators (Refs 19 & 28)

**Explosive Properties of DNB** (Refs 4,5,13 & 22): *Ballistic Strength*, 88% TNT; *Brisance* by Sand Test, 32g sand crushed vs 43g for TNT or ca 82% TNT; by Copper Block Compression Test ca 80% TNT; *Explosion Temperature*, does not deton from exposure to heat up to 360°; *Heat of Combustion*, $Q_c^v$ 698kcal/mol or 4160cal/g; *Heat of Explosion*, $Q_e^v$ 870cal/g; *Impact Sensitivity*, 18" vs 14" for TNT, Pic Arsn App with 2-kg wt or ca 135% TNT; *Power by Trauzl Test*, 85% TNT; *Rifle Bullet Sensitivity*, no detonations from impact of a cal 0.30 bullet fired at 90ft; *Stability*, completely stable and does not attack metals; *Temperature Developed on Explosion*, 2500°; *Velocity of Detonation*, ca 6100m/sec at d 1.50

*Uses*. DNB was used extensively by the Germans during WWI, mostly in admixture with TNT. It was claimed that such mixts were nearly as powerful as TNT alone(Refs 10,23 & 30). Its use in France was prohibited by the Commission des Substances Explosives because of its toxicity. Dinitrotoluene was used instead of DNB(Ref 15). Due to the shortage of TNT in Germany during WWII, DNB was again used extensively alone or in admixt with AN, RDX, Hexanitrodiphenylamine and other expls. DNB acted to desensitize other expls and it made some mixts suitable for cast loading. German Amatol type Fillers No 52 and 52A using DNB, AN and other additives, are listed in Ref 30

The Japanese also used DNB in some composite expls, such as *Shōbenyaku* or *Anbenyaku* (Ref 23). DNB has also been used as a constituent of some coml expls together with other aromatic nitrocompds and AN or K perchlorate(see Bellite, Perdite and Roburite), and in some dynamites to lower the fr p of NG(Ref 18). When used alone, DNB reqd a large amt of booster chge to effect its detonation (Ref 6)

The Russians used DNB quite extensively either straight(for cast-loading) or in mixts with other substances, such as AN (in *Bellites*), PA, TNX, TNT, etc. The *K-1 Splav* (K Cast Mixture) used during WWII for filling some cast-iron land mines consisted of DNB 30 & TNT 70%(Ref 23a)

*Refs*: 1)Beil **5**,257,(135) & [193] 2)Beil **5**,258, (135) & [193] 3)Beil **5**,261,(136) & [195] 4)W.Will,SS **1**,209(1906) 4a)J.Meisenheimer & E.Patzig,Ber **39**,2529 & 2537(1906) & JCS **90 I**, 642 & 653(1906) 5)H.Kast,SS **8**,174(1913) 6)Marshall **1**(1917),256 6a)Colver(1918),138-145 7)W.E.Garner & C.A.Abernethy, PrRoySoc **99A**, 213/35(1921) & CA **15**,3748(1921) 8)D.D.Karvé & J.J.Sudborough,JIndInstSci **4**,159-76(1921) & CA **16**,65(1922) 9)J.Stukowsky,SS **18**,14-6(1923) 10)(?) Bülov,SS **23**,170(1928) 11)W.H.Rinkenbach, JACS **52**,116(1930) 12)Stettbacher (1933),20, 257-8 & 363 13)L.Wöhler & O.Wenzelberg,Ang Chem **46**, 173(1933) & CA **27**,2579(1933) 14)A. Schmidt,SS **29**,262(1934) 15)Pepin Lehalleur (1935),161-2 16)Vennin,Burlot & Lécorché(1932), 409 17)H.W.Coward,USP 2040123(1936) & CA **30**, 4512(1936) 18)Thorpe **4**(1940),465 19)W.F.von Oettingen,USPubHealthServBull **271**(1941),94-103 & CA **36**,4596(1942) 20)OrgSynth Col Vol 2(1943), 225 21)Davis(1943), 133-4 22)Blatt,OSRD **2014** (1944) 23)All&EnExpl(1946), 111 & 157 23a) Schilling(1946),240 24)M.Glahn & P.Schack-Schou, NordiskMedicin(Stockholm) **36**,2135-6(1947) & CA **42**,4756(1948) 25)J.L.Franklin,IEC **41**,1070(1949) 26)O.K.Khaishbashev & V.E.Gromova,IzvestSektora-Fiz-KhimAnal,InstObshchei i NeorgKhimAkadNauk **17**,144-8(1949) & CA **45**,2762(1951) 27)T.E.Jordan, "Vapor Pressure of Organic Compounds", Interscience,NY(1954),Chapt 7,181 & 193-4 and Plates 14 & 16 28)(?) Kiese,Explosivst **1954**,24 29)Sax (1957), 629 30)PATR **2510** (PB No 161270)(1958), pp Ger 36-R & 47-R 31)E.Leclerc & F.Devlaminck, BullCentreBelge-EtudeDocEaux(Liège),No **14**,246 (1951/IV) & CA **46**,10507(1952) 32)PATR **2510** (PB No **161270**)(1958),p Ger 36-R(Dinitrobenzol)

**TRINITROBENZENE** (TNB)(Called Trinitrobenzol in Ger), $C_6H_3(NO_2)_3$; mw 213.11, N 19.72%, OB to $CO_2$ -56.3%. Three isomers are known and

described in the literature(the 1,3,5- or sym-TNB deriv is the most important one in the expl industry):

**1,2,3(or 1,2,6)-Trinitrobenzene (1,2,3-TNB),** col lfts with grn cast(from abs alc), mp 127°; sl sol in alc; insol in w. It was first prepd in a pure state by Körner & Contardi(Ref 10) from dinitrobenzenediazonium nitrate and $NaNO_2$ in the presence of a Cu salt. Other methods of prepn are given in Ref 1. This TNB is unstable, especially in regard to the 3rd nitro group which is easily hydrolyzed or otherwise removed

**1,2,4(or 1,3,4)-Trinitrobenzene(1,2,4-TNB),** col lfts(from eth) or lt-yel prisms(from dil alc), mp 60-2°, d 1.73 at 16°; $Q_c^v$ 676kcal/mol(Ref 17) or 3185cal/g(Refs 23 & 27); sol in benz, eth, chlf, MeOH or alc; insol in w. It was first prepd in 1882 by Hepp(Ref 3,p 34) by nitration of p-dinitrobenzene with a mixt of fuming nitric-sulfuric acids. Other methods of prepd and props are given in Refs 1 & 2

**1,3,5(or 2,4,6) or sym-Trinitrobenzene(sym-TNB)** (called Benzite in Fr), col lfts(from a large amt of boiling w), mp 121-122.5°(stable form), 61° (unstable form)(Ref 16); expl on rapid heating; d 1.688 at 20°, $Q_c^v$ 659.6 to 665.6kcal/mol(Refs 17,23 & 27). The dielectric constants of sym-TNB and associated substs have been detd by Schurz et al(Ref 37). Its sol in various solvs is as follows(Ref 1,p 203):

**Solubility of sym-TNB(g in 100g Solvent**

| Solvent | at 17° | at 50° |
|---|---|---|
| Water | 0.028(15°) | 0.102 |
| Ether | 1.70 | 2.72(32.5°) |
| Carbon disulfide | 0.239 | 0.44(33°) |
| Chloroform | 6.24 | 18.42 |
| Carbon tetrachloride | 0.237 | 0.69 |
| Benzene | 6.18 | 25.70 |
| Toluene | 11.82 | 76.31 |
| Methanol | 3.76 | 7.62 |
| Ethanol | 2.09 | 4.57 |
| Acetone | 59.11 | 160.67 |
| Ethyl Acetate | 29.83 | 52.40 |
| Pyridine | 112.61 | 194.23 |

Drummond(Ref 18,p 339T) gives a table of setting points of TNB & DNB mixts (see under Benzene, Analytical Procedures). Sym-TNB is reported by Sax(Ref 38) to be severe in toxicity resulting either from inhalation or ingestion. The effects can be both acute and chronic systemic. This compd is reported by Blatt(Ref 33) to exist in at least three polymorphic forms. The stable form crystallizes at RT as orthorhombic plates and flat rods

1,3,5-TNB was first prepd by Hepp(Ref 3,p 345) in 1882 by nitrating m-DNB with strong mixed nitric-sulfuric acid. Claus & Becker(Ref 4) proposed preparing sym-TNB by oxidg TNT with fuming nitric acid to trinitrobenzoic acid and heating in w to eliminate $CO_2$. A better method is to oxidize TNT using K or Na dichromate and concd sulfuric acid(Refs 21,31,32 & 36). Sym-TNB may also be prepd by reduction of picryl chloride with Cu, as proposed by Desvergnes(Ref 19). According to Pepin Lehalleur(Ref 25), the yields for the different methods are as follows: by direct nitration of m-DNB, 50%; by oxidn of TNT with chromate mixt, 73%; and by reduction of picryl chloride, 60%. A lab method of prepg sym-TNB is given by Davis (Ref 32,p 135). Addnl info on the prepn of sym-TNB may be found in the following Refs(5,7,12, 16,18,20a,29 & 34)

**TNB,Commercial,** yel crysts compd, mp 120-2°, d 1.67, consists principally of 1,3,5-TNB. It is considered to be a more powerful and brisant HE than TNT but it is more sensitive to impact than TNT, based on the following:

**Explosive and Other Properties**(Refs 6,8,9,11,13, 14,15,19,20,22,24, & 33): *Brisance* by Sand Test, 110% of TNT; by Lead Plate Cutting Test, about equal to PA; by Lead Block Compression Test, 111% TNT and by Copper Cylinder Compression Test 114% TNT; *Explosion temperature,* 520°; *Heat of Combustion,* $Q_c^v$ at 17°, 3096cal/g(Ref 28); *Heat of Explosion,* 1063cal/g; *Hygroscopicity,* at 25°, gains 0.05% at 100%RH; *Impact Sensitivity,* FI 109% PA or more sens than TNT and less sens than PA; 11" vs 14" for TNT on Pic Arsn Impact App; *Impact Work,* for 50% explns with 2kg wt, 12mkg/cm² or 106%TNT; *Power* by Ballistic Mortar, 105-17%TNT; by Lead Block Expansion (Trauzl Test) 108%PA & 111% TNT and by pressure Bomb 110% TNT; *Stability, Thermal.* TNB is one of the most stable HE's. Its stability by 120° Vacuum Stability Test is 0.46cc/5g in 48hrs; by 135°C Heat Test, not acid & no expln in 300min and by KI Test at 65.5°-85min; *Temperature Developed on Explosion,* 3540°(max); and *Velocity of Detonation,* 7000m/sec at d 1.64; 7350m/sec at d 1.66 in 20mm diam paper cartridges; 7440m/sec with cast expl(d 1.68)

*Uses* TNB appears to be superior to TNT in many respects. If a more satisfactory and economical

method for its prepn could be found, TNB might be used as a bursting chge in shells and bombs. Pressed TNB was used by the Germans in WWII as Filler No 70 in some primers(Refs 35,34a & 39). Also, due to the shortage of toluene in Germany during WWII, a mixt of 60% DNB and 40% TNB was satisfactorily used in loaded ammo items (bombs) where exudation was not of importance (Ref 39)

*Refs*: 1)Beil **5**,(140) & [203] 2)Beil **5**,271 3)P.Hepp,Ann **215**,345 & 361(1882) & JCS **44**, 315-6(1883) 4)Ad.Claus & H.Becker,Ber **16**, 1597(1883) 5)ChemFabrikGriesheim,GerP 77353 (1893) & SS **9**,193(1914) 6)W.Will,SS **1**,211-13 (1906) 7)J.Meyer,GerP 234726(1909) & SS **9**, 194(1914) 8)M.H.Dautriche,MP **16**,27(1911-1912) 9)H.Kast,SS **8**,173(1913) 10)G.Körner & A.Contardi,AttiAccadLin **23** II,464(1914) & CA **9**,1478 (1915) & SS **10**, 64-5(1915) 11)Marshall **1**(1917), 258 11a)Colver(1918),146-160,218,220,536,659, 673,689,732 12)M.M.Kostevitch, "TNT & TNB" Pamphlet, Maillard & Co,London(1919),38pp & CA **15**,3747(1921) 13)R.L.Datta & N.R.Chatterjee, JCS **115**,1006(1919) 14)H.Kast,SS **15**,172(1920) 15)A.Stettbacher, SS **16**,139(1921) 16)L.G.Radcliffe & A.A.Pollitt,JSCI **40**,45-48T & 90T(1921) & CA **15**, 2356(1921) 17)W.E.Garner & C.L.Abernethy,PrRoySoc **99A**,213(1921) & CA **15**,3748 (1921) 18)A.A.Drummond, JSCI **41**,338-340T (1922) & SS **17**,169-70(1922) 19)M.L.Desvergnes, MP **19**, 221-3(1922) 20)W.M.Dehn & A.A.Wagner, ArOrdn **8**,35(1927) 20a)S.Secareanu,BullFr[4] **51**,591-6(1932) & CA **26**,5081-2(1932) 21)Stettbacher(1933),162 22)L.Wöhler & O.Wenzelberg, AngChem **46**,173(1933) & CA **27**,2579(1933) 23)A. Schmidt,SS **29**,262(1934) 24)A.Majrich & F.Sorm, SS **30**,338(1935) 25)Pepin Lehalleur(1935),162 26)Vennin,Burlot & Lécorché(1932),409 27)E. Burlot & M.Thomas,MP **29**,262(1939) & CA **34**, 1849(1940) 28)M.Badoche, BullFr[5] **6**,570 (1939) & CA **33**,5736(1939) 29)J.R.Johnson, OSRD **160**(1941) & PB Rept **31092** 30)R.Adams & C.S.Marvel,OSRD **312**(1941) & PB Rept **31095** 31)OrgSynthCollVol 1(1941),543 32)Davis(1943), 134-40 33)Blatt,OSRD **2014**(1944) 34)H.Aaronson, PATR **1562**(1945) 35)C.H.Brooks,PB Rept **22930**(1945) 35a)All&EnExpl(1946),112 36)M.L. Kastens & J.F.Kaplan,IEC **42**,402(1950) & CA **44**,4441(1950) 37)J.Schurz et al, Monatsh **86**, 986-94(1955) & CA **50**,6117(1956) 38)Sax(1957), 1222-3 39)PATR **2510**(PB No **161270**) (1958), p Ger 48 40)M.Blais et al, PATR **2587**(1959),"Preparation of Thermally Stable Explosives :Evaluation of 2,4,6-TNB"(Conf) (Not used as a source of info) 41)G.Desseigne, MP **43**,7-13(1961)(Prepn of TNB by decarboxylation of TNBAc formed on oxidation of TNT with sulfochromic acid)

### TNB Additive Compounds, Complexes and Other Derivatives

There exists a large group of cryst complexes contg in stoichiometric proportions polynitro -aromatic substs, such as TNB or PA, and aromatic hydrocarbons and bases and their derivs. These complexes are, for the most part, unstable, and some of them are expl. Some examples of these are the following:

*1,3,5-TNB+Sodium Methylate*, $C_6H_3(NO_2)_3+2CH_3.ONa$; red amor subst, expl violently on rapid heating to ca 100°(Ref 6)

*1,3,5-TNB+Potassium Methylate*, $C_6H_3(NO_2)_3+CH_3.OK+1/2H_2O$; red crysts, expl violently when heated on a Pt foil(Ref 2)

*1,3,5-TNB+Potassium Methylate+Acetone*, $C_6H_3(NO_2)_3+CH_3.OK+1/2CH_3.CO.CH_3$; dk-grn ndls (from acet thru eth), stable on heating to 100° but expl at higher temps(Ref 8)

*1,3,5-TNB+Hydrogen Cyanide*, $C_6H_3(NO_2)_3+HCN$; red ndls(from alc or eth), dec ca 175°; the *K salt*, $KC_7H_3O_6N_4$, dk viol cryst mass, expl mildly on heating (Ref 4)

*1,3,5-TNB+Hydroxylamine and Sodium Methylate*, $C_7H_{11}O_9N_6Na_3$; red, fine-grained crysts contg 2-3 moles $H_2O$, expl mildly on rapid heating (Ref 7)

*1,3,5-TNB+Phenylhydrazine*, $C_6H_3(NO_2)_3+C_6H_5N_2H_3$, dk-red, long flat prisms which sinter at 75-80° and dec with sl expln(Ref 10)

*1,3,5-TNB+Hydrazine* $C_6H_3(NO_2)_3+2N_2H_4$; grn shiny prisms, mp 122-3°(dec), expl mildly on heating in a free flame(Ref 10)

*1,3,5-TNB+Sodium Hydroxide*, $C_6H_3(NO_2)_3+NaOH$; red-brn cryst ppt, expl on heating(Ref 11)

*1,3,5-TNB+Potassium Propylate*. $C_6H_3(NO_2)_3+3CH_3.CH_2.CH_2.OK$, finely dispersed red, unstable solid, expl(Ref 9)

*1,3,5-TNB+Ethylsodioacetoacetate*, $C_6H_3(NO_2)_3+3CH.CH_3.CO.Na.COOC_2H_5$; brn-red amor powd, expl on heating(Ref 5)

*1,3,5-TNB+Ethylsodiomalonate*, $C_6H_3(NO_2)_3+3CH.Na(COOC_2H_5)_2$; maroon amor powd; expl on heating(Ref 5)

*1,3,5-TNB+Acetone and Alkali*, reaction gave a blk solid complex which is expl(Ref 12). Similar compds, prepd by one of the authors(BTF) during WWII, from TNT, acet and aw KOH were found

to be expl

Complexes of sym-TNB with aromatic hydrocarbons and amines in $CHCl_3$ solns were prepd by Bier(Ref 13) who detd their equil constants, enthalpy and energy of formation

*Refs*: 1)Beil **5**,272-3 & (140) 2)C.A.L.de Bruyn & F.H.van Leent,Rec **14**,150 1895) & JCS **70** I, 1478(1896) 3)J.L.Heinke,Ber **31**,1398(1898) & JCS **74** I, 413(1898) 4)A.Hantzsch & H.Kissel, Ber **32**,3144(1899) & JCS **78** I,90(1900) 5)C.L. Jackson & F.H.Gazzolo,AmChemJ **23**,376(1900) & JCS **78** I,433-4(1900) 6)C.L.Jackson & R.B. Earle,AmChemJ **29**,114(1903) & JCS **84** I,339 (1903) 7)J.Meisenheimer & E.Patzig,Ber **39**, 2539(1906) & JCS **90** I,653(1906) 8)A.Hantzsch & N.Picton,Ber **42**,2125(1909) & JCS **96** I,468 (1909) 9)M.Busch & W.Kögel,Ber **43**,1563(1910) & JCS **98** I,474(1910) 10)K.A.Hofmann & H.Kirmrenther,Ber **43**,1765(1910); CA **4**,2801(1910) & JCS **98** I,548-9(1910) 11)M.Giua,Gazz **45** II,351 (1915) & JCS **108** I,885(1915) 12)M.Kimura, JPharSoc(Japan) **73**,1216-23(1953)& CA **48**, 12699(1954) 13)A.Bier,Rec **75**,866-70(1956) & CA **50**,16332(1956) 14)M.Blais et al,PATR **2524**(1959), "Preparation of Thermally Stable Explosives: 2,4,6-Trinitrobenzene Derivatives (Conf Rpt, not used as a source of info)

**Trinitrobenzeneazonaphthalene.** See under Benzeneazonaphthalene and Derivatives

**Trinitrobenzeneazonaphthol.** See under Benzeneazonaphthol and Derivatives

**Tetranitrobenzene (TeNB)** (called Tetranitro-benzol in Ger), $C_6H_2(NO_2)_4$; mw 258.11, N 21.7%, OB to $CO_2$ - 31.0%. Two isomers, both powerful expls, are described in the literature: **1,2,3,5(or 1,3,4,5-TeNB**, yel ndls(from chlf), mp 125-6°, d 1.61; cryst structure detd by Hertel & Römer(Ref 6) but erroneously called 1,2,4,6-TeNB; readily sol in acet or glac AcOH; sol in alc, diffc sol in benz or eth. The NaOH soln is red but becomes yel on heating. Desvergnes(Ref 5) reported that TeNB is insol in w, but it is decompd by it(even in the cold) to PA and $HNO_2$. Alc, eth, acet and other compds contg oxygen decomp TeNB and for this reason can not be used as solvs for its purification. It is necessary to use hydrocarbons or halogenated hydrocarbons for this purpose. Solubilities of TeNB according to Desvergnes (Ref 5) are as sollows: in benz 2.29% at 23°; chlf 0.58% at 23°; carbon disulfide 0.09% at 23°; and in $CCl_4$ 0.04% at 25°; pyridine dissolves TeNB immedy with a brisk efflorescence and rise in temp; toluene decomps it even in the cold

1,2,3,5-TeNB was first prepd in 1923 by Borsche (Refs 1 & 2) by heating picrylhydroxylamine with fuming $HNO_3$ on a w bath; later by Holleman(Ref 4) by heating picramide with nitric acid satd with nitrous fumes and by Desvergnes(Ref 5) who treated 2,4,6-trinitroaniline with nitric acid and purified the crude product by crystn from benz. Earlier descriptions of the prepn of TeNB are erroneous (Ref 1,p 276). Pepin Lehalleur(Ref 7) describes in detail a lab procedure based on Holleman's method

**Explosive Properties** (Ref 8). 1,2,3,5-TeNB is an extremely powerful and brisant expl and is more sens to impact than TNT: *Impact Sensitivity*, FI 67% PA; by Kast App, 2kg wt- 25cm vs 83cm for PA; *Power*, by Trauzl Test- ca 150% TNT; *Stability*, no decpmn in 6hrs at its mp temp, but the $NO_2$ group in the 2 position is readily hydrolyzed

**1,2,4,5-TeNB**, lt yel crysts(from dil alc), mp 188°. It can be prepd by warming on a w bath 4,6-dinitro -1,3-dihydroxylaminobenzene (or 2,4-dinitro-1,5-dihydroxylaminobenzene), $C_6H_2(NHOH)_2(NO_2)_2$, with concd nitric acid (d 1.52)(Ref 3)

*Uses*: Coml TeNB which is a mixt of the above isomers, should be suitable for use in booster expls or as a secondary chge in detonators. Its toxicity is not known(Ref 9)

*Refs*: 1)Beil **5**,276,(141) & [207] 2)W.Borsche, Ber **56B**,1942(1923) & CA **18**,533(1934); Ber **63B**, 1007(1930) & CA **24**,3767(1930) 3)W.Borsche & E.Feske,Ber **59B**, 820(1926) & CA **20**,2667(1926) 4)A.F.Holleman,Rec **49**,112-20(1930) & CA **24**, 2440-1(1930) 5)L.Desvergnes,RevChimInd **40**, 34-7(1931) & CA **25**,2980-1(1931) 6)E.Hertel & G.H.Römer,ZPhysChem [B] **22**,277(1933) & CA **27**,5228(1933) 7)Pepin Lehalleur(1935),165 8)Blatt,OSRD **2014**(1944) 9)Sax(1957)-not listed

**Pentanitrobenzene**, $C_6HN_5O_{10}$; its prepn was attempted by van Rijn(Ref 2) accord-to the method of Borsche(see above) in which the $NH_2OH$ group is oxidized to $NO_2$ with abs $HNO_3$ but the reaction failed to produce the desired product

*Refs*: 1)Beil- not found 2)P.J.van Rijn,Rec **45**, 257(1926) & CA **20**,2317(1926)

**Hexanitrobenzene**, $C_6N_6O_{12}$; its prepn was attempted by van Rijn(Ref 2) following the method of Borsche(see above) but the reaction failed to produce the desired product

*Refs*: 1)Beil-not found 2)P.J.van Rijn,Rec **45**, 257(1926) & CA **20**,2317(1926)

**Benzene, Nitro Derivatives, Analytical Procedures**

**Mononitrobenzene**(MNB) can be detected and estimated by one of the following methods: a)*Aniline Method* consists of treating a MNB-contg sample with Zn-HCl to reduce MNB to aniline and estimating the amt of aniline(Ref 8,pp 710 & 722-3) b)*Dinitrobenzene Method* consists of treating a MNB-contg sample with mixed nitric-sulfuric acid and estimating the amt of DNB produced as result of the nitration(Ref 8,p 524 & 723)

*Note:* No color is produced when an acetonic soln of MNB is treated with aq NaOH(Ref 5)

**Dinitrobenzenes.** Of these, only the m-isomer is of importance in the expls industry. For its detection and estimation, there may be used the reduction method proposed by Smyth et al(Refs 4 & 5). In this method the m-DNB is reduced by addg an excess of standard titanous chloride soln to diaminobenzene and the excess of titanous chloride is detd by titration with std ferric alum soln. The following reactions take place:

$$C_6H_4(NO_2)_2 + 2TiCl_3 + 12HCl \longrightarrow C_6H_4(NH_2)_2 + 12TiCl_4 + 2H_2O$$

$$2TiCl_3 + 2HCl + Fe_2(SO_4)_3 \longrightarrow 2TiCl_4 + 2FeSO_4 + H_2SO_4$$

A detailed description of this method in modified version, is given by Jacobs(Ref 8,pp 531-6)

A soln of m-DNB produces with NaOH an intense red-violet coloration and with ammonia rose-red to purple-red(Ref 2)

Bost & Nicholson(Ref 6) dissolve ca 0.1g sample in 10ml acetone and add 3ml of 5% NaOH soln. No color is produced with MNB but a purplish-blue color is produced with m-DNB which becomes light purple on dilution with w and yel-brn on addn of HCl. Cruse & Haul(Ref 7) describe a polarographic method of detng m-DNB. In Organic Analysis(Ref 9) a gravimetric method is described for the detn of DNB by weighing the undissolved tin. This method is not applicable to TNB

Detns of m-DNB in mixts with s-TNB are briefly described under the next item(see also Ref 3)

*Refs*: 1)Beil **5**,240 & [179] (Mononitrobenzene) 2)Beil **5**, [195] (1,3-Dinitrobenzene) 3)A.A.Drummond,JSCI **41**,338T(1922) 4)H.F.Smyth,Jr,JIndHyg **10**,163(1928) 5)H.F.Smyth,JIndHyg **11**,338 (1929) & **13**,227(1931) 6)R.W.Bost & F.Nicholson, IEC,AnalEd **7**,190(1935) 7)K.Cruse & Haul,Z-Elektrochem **53**,115-17(1949) & CA **43**,8978(1949) 8)Jacobs(1949),531-6 & 722-3 9)Organic Analysis, Interscience,NY **2**(1954),90-1 10)Dr Hans Walter,PicArsn; private communication (1961)

**Trinitrobenzenes.** Of these, only the s(or 1,3,5)-TNB is of importance as an explosive. It can be detected and estimated by colorimetric or by other tests

Bost & Nicholson(Ref 3) describe a method in which ca a 0.1g sample is dissolved in 10ml acetone and 3ml of 5% NaOH soln is added. An intense red coloration is produced which turns lt red on dilution with w and becomes blood red on addn of HCl

Moss & Mellon(Ref 4) describe a quantitative colormetric detn of s-TNB when in mixts with m-DNB. For this, ca a 50-100mg sample is dissolved in 50ml of 95% ethanol and an aliquot 0.1 to 1.0mg TNB is withdrawn to a 50ml volumetric flask. To this is added 0.5ml of 10% NaOH soln and then(with shaking) ethanol is added to the 50ml mark. After allowing to stand for 10 mins, the intensity of coloration is measured colormetrically, using a blue-green filter, such as Corning No 396

Cruse & Haul(Ref 5) describe a polarographic method of detn of s-TNB. Siggia(Ref 7) and Organic Analysis(Ref 8) describe a titanous chloride reduction method which is applicable to s-TNB. Shriner et al(Ref 9) give the mp of the naphthalene addn compd as 153°, which may be used for identification of s-TNB

Drummond(Ref 2) stated that attempts to separate TNB from DNB by fractional crystallisation from alc and $CCl_4$ or by fractional pptn from nitrating acids were not successful. More promising results were obtained by formation of compds of TNB+aniline

A rapid estimation of TNB & DNB contents may be made by detg the setting point of the mixt and comparing the value obtained with setting points given in the following table(Ref 2, p 339T)

See Table Following Page

Setting Points of Mixtures

| % m-DNB | % s-TNB | Setting Point °C |
|---|---|---|
| 0 | 100 | 121 |
| 22.4 | 77.6 | 96.3 |
| 30.4 | 69.6 | 85.7 |
| 36.9 | 63.1 | 75.3 |
| 41.2 | 58.8 | 70.7 |
| 44.8 | 55.2 | 64.9 |
| 47.0 | 53.0 | 61.4 |
| 49.5 | 50.5 | 57.2 |
| 50.7 | 49.3 | 57.8 |
| 53.4 | 46.6 | 57.8 |
| 57.2 | 42.8 | 60.3 |
| 62.8 | 37.2 | 65.2 |
| 71.3 | 28.7 | 71.5 |
| 75.1 | 24.9 | 74.5 |
| 80.8 | 19.2 | 78.0 |
| 87.3 | 12.7 | 82.0 |
| 100 | 0 | 89.5 |

Since mp's betwn 89.5 and 57.2° represent two different compns, the one contg an excess of DNB and the other contg an excess of TNB, it is necessary to distinguish between them. For instance, if a mixt has a setting point of 71.0°, it may consist of either ca 42% DNB & 58% TNB or ca 70% DNB and 30% TNB. In order to det which of these compns is present, a weighed portion of sample (ca 1g) is placed on a porous plate and the ensemble inserted in an oven maintained at 60°, which is slightly above the eutectic temp(ca 57.2°). After about one hour the plate is removed and the unabsorbed portion of the sample is tested colorimetrically for TNB or DNB. In this test all the eutectic(which is a 50/50 compn) is melted and absorbed, leaving on the surface of the plate the compd which is in excess of 50%. The unabsorbed portion can be weighed and its mp can be detd

A more precise procedure for analysis of DNB -TNB mixts, communicated to us by Dr Walter (Ref 10), consists of the following operations:
a) Treat the TNB-DNB mixt with stannous chloride in HCl to obtain 1,3,5-triamino- and 1,3-diamino-benzenes
b) Bring the soln to pH 7 and boil it. This operation transforms the triamine to phloroglucinol and leaves the diamine unaltered
*Note*: The presence of phloroglucinol can be detected by ferric chloride(blue coloration) or by other phenolic reaction methods
c) Make the soln alkaline with KOH. This gives K phloroglucinate and phenylenediamine(free base)
d) Extract the phenylenediamine with benz, evaporate the solvent and weigh the residue
*Note*: Phenylenediamine may be detected as Bismarck Brown by treating with Na nitrite
e) Acidify the phloroglucinate and extract the free phloroglucinol with ether, evaporate the solvent and weigh
*Note*: Another method is to nitrate the residue to trinitrophloroglucinol, precipitate it as Pb phloroglucinate, weigh the salt and det its mp
*Refs*: 1)Beil- no analytical procedures given 2)A.A.Drummond,JSCI **41**,339T 3)R.W.Bost & F.Nicholson,IEC,AnalEd **7**,191(1935) 4)M.L. Moss & M.G.Mellon,IEC,AnalEd **14**,806-1(1942) 5)K.Cruse & R.Haul, ZElektrochem **53**,115-17 (1949) & CA **43**,8978(1949) 6)Jacobs- not found 7)Siggia(1949),84 8)Organic Analysis,Interscience, **2**(1954),73-4 9)Shriner,Fuson & Curtin (1956),324 10)Dr Hans Walter,PicArsn; private communication(1961)

**Benzeneazoacetaldoxime**,, $C_6H_5.N{:}N.C(:N.OH)\text{-}CH_3$; mw 163.18, N 25.75%; orn-yel crysts, mp 118.5-119.5°; readily sol in alc, eth, chlf, benz or boiling ligroin; diffc sol in petr eth. Prepn and other props are given in the Refs. It forms salts, some of which are expl: *Silver salt*, $AgC_8H_8N_3O$, orn crysts, mp- expl ca 80° and *Sodium salt*, $NaC_8H_8N_3O$, lt yel ndls, mp- expl; very easily sol in w, alc or hot AcOH; insol in eth or benz
*Refs*: 1)Beil **16**,14-5,(220) & [7] 2)H.Voswinckel,Ber **32**,2485(1899) & **33**,2795(1900) 3)E.Bamberger & W.Pemsel,Ber **36**,56(1903)

**Benzeneazoacetaldoxime Picrylester** (called O-Pikryl-benzolazoacetaldoxim in Ger), $C_6H_5.N{:}N.C(CH_3){:}N.O.C_6H_2(NO_2)_3$; mw 374.27, N 22.46%; orn ndls(from benz+ligroin), mp- expl ca 140°; easily sol in benz; insol in alc or ligroin. Can be prepd from the Na salt of benzeneacetaldoxime and picrylchloride in abs alc soln
*Refs*: 1)Beil **16**,15 2)H.Voswinckel,Ber **33**, 2798(1900) & **35**,3271(1902)

## Benzeneazo-carboxy-phenyl-triazole and Derivatives

**4-(Benzeneazo)-5-carboxy-2-phenyl-β-vic (or 2,3,1)-triazole** [called 5-Benzolazo-2-phenyl-1,2,3-triazol-carbonsäure-(4) or C-Benzolazo-N-phenyl-osotriazol-C-carbonsäure in Ger],

mw 293.28, N 23.88%; orn-yel lfts(from alc or dil AcOH), mp 195°; nearly insol in w or ligroin; sol in alc, AcOH and many other org solvents. Was obtained, together with other products, on heating phenylhydrazone of N, N'-diphenylformazylglyoxylic acid with AcOH

Its *Silver salt*, $AgC_{15}H_{10}N_5O_2$, yel solid, insol in w, is a mild expl and probably so are the Ba, Cu, Hg and Pb salts

*Refs*: 1)Beil **26**,342 2)E.Bamberger & J.Müller, Ber **27**,152-3(1894)

*Azido*-$C_{15}H_{10}N_8O_2$, *Diazido*-$C_{15}H_9N_{11}O_2$, *Mononitro*-$C_{15}H_{10}N_6O_4$, *Dinitro*-$C_{15}H_9N_7O_6$, *Trinitro*-$C_{15}H_8N_8O_8$ and *Tetranitro*-$C_{15}H_7N_9O_{10}$ *Derivatives* were not found in Beil or in CA through 1956

**Benzeneazomethane and Derivatives**

*Benzeneazomethane*(called Methyl-phenyl-diimid; Methanazobenzol or Benzolazomethan in Ger), $C_6H_5.N{:}N.CH_3$; mw 120.15, N 23.32%; yel oil, bp-distills at ca 150°; very easily volat on a steam bath. Its prepn and other props are given in Beil **16**,7

**Benzeneazotrinitromethane or Phenylazotrinitromethane** *(Benzeneazonitroformate)* [called *1',1',1'-Trinitrobenzeneazomethane* in CA, Dec FI (1947-56),p 227F], $C_6H_5.N{:}N.C(NO_2)_3$; mw 215.15, N 27.45%; yel powd, mp- expl when dry with great violence at 70-5°; cannot be crystd from org solvs because of decompn. It was prepd by Quilico(Ref 2) (in the course of his study of the reaction betw acetylene and fuming $HNO_3$) by treating an aq Amm nitroformate soln with benzene diazoniumchloride in the presence of Na acetate. The subject compd dec rapidly at RT or when heated in an inert solv. It expl with great violence by percussion. Also see Vol 1, p A67-R

Its decompn reactions by free radicals have been studied(Ref 3)

*Refs*: 1)Beil- not found 2)A.Quilico,Gazz **62**, 503-18 & 912-27(1932) & CA **26**,5954-5(1932) & **27**,1348(1933) 3)G.A.Razuvaev & E.I.Fedotova, ZhObshchKhim **21**,1118-22 & 1219-23(English translation)(1951) & CA **46**,5006-7 & 7534(1952)

**p-Nitrobenzeneazotrinitromethane**, $p\text{-}O_2N.C_6H_4.N{:}N.C(NO_2)_3$; mw 300.15, N 28.00%; orn-yel powd, mp- expl with less violence than the compd above. It was prepd by diazotizing Amm formate with $p\text{-}O_2N.C_6H_4N_2Cl$ in the presence of Na acetate

Also see Acetylene-Nitric Acid Reaction Studies, Vol 1,A67-R

*Refs*: Same as Refs 2 & 3 above

**3,5-Dinitrobenzeneazotrinitromethane** is described in Conf US Rubber Co Final Rpt on Contract NORD 10129

*Trinitrobenzeneazotrinitromethane*, $C_7H_2N_8O_{12}$- not found in Beil or in CA thru 1956

**Benzeneazoaniline.** Same as Aminoazobenzene, Vol 1,p A184-R

**Benzeneazobenzene.** Same as Azobenzene, Vol 1, p A646-R

**Benzeneazodiphenylamine.** Same as Anilinoazobenzene, Vol 1,p A420-R

**Benzeneazonitroformate.** Same as Benzeneazotrinitromethane

**Benzeneazonaphthalene and Derivatives**

*Benzeneazonaphthalene*(called Phenyl-α-naphthyl -diimid; 1-Benzolazo-naphthalin or Benzol-azo--naphthalin in Ger), $C_6H_5.N{:}N.C_{10}H_7$; mw 232.27, N 12.06%, is described in Beil **16**,78

*Mononitrobenzeneazonaphthalene*, $O_2N.C_6H_4.N{:}N.C_{10}H_7$; mw 277.27, N 15.16%. The [*3-Nitrobenzene*] -*azo-α-naphthalene*, isomer is described in Beil **16**,78

*Dinitrobenzeneazonaphthalene*, $(O_2N)_2C_6H_3.N{:}N.C_{10}H_7$; mw 322.27, N 17.39%. Two isomers are described in Beil **16**,78 & [80]

**Trinitroazonaphthalene**, $C_{10}H_7.N{:}N.C_6H_2(NO_2)_3$; mw 367.27, N 19.07%. Two isomers are described in the literature:[2,4,6 -*Trinitrobenzene*] -*azo-α-naphthalene*,Red-yel ndls (from glac AcOH, mp 226° (dec); readily sol in glac AcOH; diffc sol in benz or alc; and [*2,4,6 -Trinitrobenzene*] -*azo-β-naphthalene*, dull-red ndls(from glac AcOH), mp ca 205°(dec). The prepn of these isomers is given in Beil **16**,78 & 80 as reported by C.Willgerodt & F.Schulz, JPraktChem **43**,181-2(1891) & JCS **60** I,572 (1891). Their expl props were not detd

**Benzeneazonaphthol and Derivatives**

*Benzeneazonaphthol*, $C_6H_5.N{:}N.C_{10}H_6.OH$; mw 248.27, N 11.28%. Three isomers are described in Beil **16**,151,154,162,(248,251,254) & [67.70]

*Mononitrobenzeneazonaphthol*, $O_2N.C_6H_4.N{:}N.C_{10}H_6.OH$, mw 293.27, N 14.33%. Eight isomers are described in Beil **16**,151,155 165,(248,251,255) & [67,68,70] *Dinitrobenzeneazonaphthol*. $(O_2N)_2C_6H_3.N{:}N.C_{10}H_5.OH$, mw

338.27. N 16.56%. Two isomers are described in Beil **16**,(252,255) & [71]

**Trinitrobenzeneazonaphthol,** $(O_2N)_3C_6H_2.N{:}N.C_{10}H_6.OH$; mw 383.27, N 18.27%. Three isomers are described in the literature: [*2,4,6-Trinitrobenzene*] - <*1 azo 2*>-(*1*)-*naphthol,* brn ndls (from glac AcOH); mp 230°(dec); sol in aq NaOH, giving a violet color; sol in $H_2SO_4$, giving an olive-grn color(Ref 1)
[*2,4,6-Trinitrobenzene*] - <*1 azo 4*>-(*1*)-*naphthol,* yel-brn or dk-red, blue shiny crysts(from glac AcOH); mp 249°; sol in cold dil NaOH, giving a blue-viol color; sol in $H_2SO_4$, giving a purple -red color. Forms blue, golden shiny Na & K salts(Ref 2) and
[*2,4,6-Trinitrobenzene*] - <*1 azo 1*>-(*2*)-*naphthol,* grn-blue crysts(from glac AcOH) or red-brn cubes (from MNB), mp 290-2°(dec); sol in concd $H_2SO_4$, giving a blue-viol color; mod sol in benz; diffc sol in boiling alc(Ref 3). The prepn of these isomers is given in the Refs. These compds are probably mild expls
*Refs:* 1)Beil **16**, [67] 2)Beil **16**, [68] 3)Beil **16**, [71]

**Benzeneazonitronaphthol and Derivatives**

*Benzeneazonitronaphthol,* $C_6H_5.N{:}N.C_{10}H_5(NO_2)$-OH; mw 293.27, N 14.33%. Three isomers are described in Beil **16**,153,161 & (267)

*Mononitrobenzeneazonitromaphthol,* $O_2N.C_6H_4.N{:}N.C_{10}H_5(NO_2).OH$; mw 338.27, N 16.56%. Four isomers are described in Beil **16**,154,161,(268) & [67]

**Dinitrobenzeneazonitronaphthol,** $(O_2N)_2C_6H_3.N{:}N.C_{10}H_5(NO_2).OH$; mw 383.27, N 18.27%. Only the [*2,4-Dinitrobenzene*] -<*1 azo 1*>-[*4-nitro-(2) -naphthol*], dk-red, greenish shiny lfts(from anisole), mp 205-250°; sol in concd $H_2SO_4$, giving an indigo-blue soln, is described in Beil **16**, (268). This compd is probably a mild expl

*Trinitrobenzeneazonitronaphthol,* $(O_2N)_3C_6H_2.N{:}N.C_{10}H_5(NO_2).OH$ - not found in Beil or in CA thru 1956

**Benzeneazonitroformate.** See Benzeneazotrinitromethane

**Benzene Carbonol.** See Benzaldehyde

**Benzene Carbon Amide.** See Benzamide

**Benzenediammonium Hydroxide.** This compd, of which the Azido deriv is listed in Vol 1,p A630 -L, should read Benzenediazonium Hydroxide. See under Benzene Diazo- and Diazonium Derivatives

**Benzenediazoanilide.** Same as Diphenyltriazene

## BENZENE DIAZO-AND DIAZONIUM DERIVATIVES

The aromatic diazo compds contain the characteristic group(-N:N-) which has replaced one H atom of a cyclic system. The group shows both mula $[Ar.N_2]^+X^-$ are formed with acids and of the formula $[Ar.N_2.O^-]Na^+$ with bases. The diazo compds are very reactive and are usually expl. They are formed when nitrous acid acts at low temp on salts of aromatic amines

Diazo compds were discovered by Griess in 1858. The procedure by which these compds are formed is called "diazotization". The diazo compds are not isolated from their solns as such but in the form of salts or bases, called "diazonium compounds". Lower members of the aromatic diazo compds are very violent expls and for this reason only small quants should be prepd at a time. As the amt of carbon in a compd is increased the expl props become weaker. For example, diazo compds of toluene, xylene, naphthalene, etc are less violent expls and less sensitive than the corresponding compds of benzene
*Refs:* 1)Beil **16**,427,(352) & [268] 2)P.Griess, Ann **106**,123(1858); **113**,201(1860); **121**,257(1862); 137,39(1866) 3)P.Griess,PrRoySoc **9**,594(1858); **11**,263(1861); **12**,418(1862); **13**,375(1864) 4)A. Eibner, "Zur Geschichte der aromatischen Diazo Verbindungen", München-Berlin(1903) 5)J.C. Cain, "Chemistry and Technology of Diazo Compounds",London(1920) 6)A.Hantzsch & G.Reddelien, "Die Diazoverbindungen",Berlin(1921) 7)N.V.Sidgwick,"The Organic Chemistry ofNitrogen",Oxford,Clarendon Press(1942) 8)E.F.Degering,"An Outline of Organic Nitrogen Compounds", University Lithoprinters,Ypsilanti,Michigan(1945), 334-363(contains 330 references) 9)W.J.Hickinbottom,Reactions of Organic Compounds, Longmans,Green & Co,London(1948),259 10)K.H. Saunders, "The Aromatic Diazo-Compounds and Their Technical Applications",E.Arnold & Co, London(1949) 11)P.Karrer, "Organic Chemistry", Elsevier,Amsterdam(1950),293,522 & 836(Ali-

phatic Diazo compounds) and pp 476 & 818(Aromatic Diazo Compounds) 12)L.F.Fieser & Mary Fieser, "Organic Chemistry", Heath & Co,Boston (1950),644,649-661 13)R.C.Fuson,"Advanced Organic Chemistry", J.Wiley & Sons,NY(1950), 520,548-572

**Benzene Diazonium Chloride**(Diazobenzene Chloride), $C_6H_5.N_2.Cl$; mw 140.57, N 19.94%, OB to $CO_2$ -165% col ndls(from alc by pptn with eth), readily sol in w or cold AcOH; sol in abs alc or acet; insol in benz, chlf, eth or ligroin. Can be prepd by reacting equim amts of aniline and sodium nitrite in the presence of an excess of a mineral acid at low temp(0-5°). Other methods of prepn and props are given in the Refs. Its toxicity is unknown(Ref 4)

This compd is hygr but the dry salt is sensitive and expl on impact. It forms many expl salts and addn compds, such as: *Chloride + Bismuth Chloride*, $C_6H_5.N_2.Cl+BiCl_3$, col lfts, mp 85-7°(dec), expl ca 120°; *Chlorodibromide*, $C_6H_5.N_2.ClBr_2$, red-yel cryst pdr, mp 61°, very unstable; *Dichloroiodide*, $C_6H_5.N_2.Cl_2I$, yel ndls or lfts(from alc), mp 86-7°(dec); *Chloride+Lead Chloride*, $2(C_6H_5.N_2.Cl)+PbCl_4$, straw-yel lfts, mp- unstable, expl ca 80-1°; *Chloride+Mercuric Chloride*, $C_6H_5.N_2.Cl+HgCl_2$, wh ndls, mp. dec ca 122°; *Chloride+Mercuric Cyanide*, $C_6H_5.N_2.Cl+2Hg(CN)_2+H_2O$, ndls, mp- expl ca 107°; *Chloride+Chloroplatinate*, $2(C_6H_5.N_2.Cl)+PtCl_4$, yel prisms, mp- expl on heating; and *Benzenediazonium Chloride+Zinc Chloride*, $C_6H_5.N_2.Cl+ZnCl_2$; the pptd compd, dried by washing with acet, expl on storage in a vacdesic after 15 hrs at RT(Ref 3)

*Refs*: 1)Beil **16**,431,(352) & [268] 2)Karrer (1950), pp 461-2 3)G.D.Muir, Chem&Ind(Paris) **1956**,58 -9 & CA **50**,9021-2(1956) 4)Sax(1957),545-6

**Benzenediazonium Hydroxide and Derivatives**

**Benzenediazonium Hydroxide(Diazobenzene Hydrate)**, $C_6H_5.N_2.OH$; mw 122.12, N 22.94%. This compd exists as the normal or syn- and the iso or anti-diazonium hydroxide. Both forms exist only in solns because they decomp easily into phenol and nitrogen. They readily form salts, many of which are expl: *Silver-benzene-normaldiazotate*, $AgC_6H_5N_2O$, gray-wh crysts, explg violently on heating to ca 118°; *Potassium-benzene-isodiazotate*, $KC_6H_5N_2O$, wh lfts, explg on heating above 130°; *Silver-benzene-isodiazotate*, $AgC_6H_5N_2O$, wh crysts, explg violently on heating to high temp; and other metal salts(Ref 2)

*Refs*: 1)Beil **16**,433,(352) & [268] 2)R.Ciusa et al, Gazz **85**,1501(1955) & CA **50**,10669(1956)

**4-Azidobenzenediazonium Hydroxide**, $N_3.C_6H_4.N_2.OH$; exists only in the form of its salts, some of which are expl. They are described in Beil **16**,493

**Mononitrobenzenediazonium Hydroxide**, $O_2N.C_6H_4.N_2.OH$; mw 167.12, N 25.15%. The 2-Nitro, 3-Nitro and 4-Nitro isomers in both the normal and iso forms are described in the literature. Following are some of their expl salts: *2-Nitrobenzenediazonium Nitrate*, $O_2N.C_6H_4.N_2.O.NO_2$, wh plates, expl on heating; *2-Nitro-benzenediazonium salt of 2-nitrobenzenesulfinic Acid*, $O_2N.C_6H_4.N_2.O.SO.C_6H_4.NO_2$, yel crysts expl violently ca 100°; *2-Nitrobenzenediazonium Chloride+Lead Chloride*, $2(O_2N.C_6H_4.N_2.Cl)+PbCl_4$; yel crysts, expl ca 120-22°; *3-Nitrobenzenediazonium Nitrate*, $O_2N.C_6H_4.N_2.O.NO_2$, wh ndls, expl violently on heating; *3-Nitrobenzenediazonium Chloride+Lead Chloride*, $2(O_2N.C_6H_4.N_2.Cl)+PbCl_4$, wh lfts, expl ca 160-3°; *4-Nitrobenzenediazonium Chloride*, $O_2N.C_6H_4.N_2.Cl$, col ndls, dec with expln ca 85°; *4-Nitrobenzenediazonium Bromide*, $O_2N.C_6H_4.N_2.Br$, citron-yel lfts, very expl; *4-Nitrobenzenediazonium Azide*, $O_2N.C_6H_4.N_2.N_3$, wh ppt, expl in dry state; and *Picrate*, yel ndls, dec ca 109-10° with frothing and turning brn; *4-Nitrobenzenediazonium salt of Naphthalene Sulfonic Acid*, $O_2N.C_6H_4.N_2.O_3S.C_{10}H_7$, solid, expl on heating; *4-Nitrobenzenediazonium Chloride + Lead Chloride*, $O_2N.C_6H_4.N_2.Cl+PbCl_4$, yel lfts, dec on long storage, expl ca 132-3°(Ref 1)

Ciusa & Oreste(Ref 2) prepd numerous metallic salts of *2-Nitrobenzene-isodiazonium Hydroxide* and found the Ni,Cu,$Fe^{++}$,Al,Cd,Co & uranyl salts defgr when heated, while the Co & Cd salts expl when treated with concd sulfuric acid

*Refs*: 1)Beil **16**,480,482 & 483,(356,357 & 358) & [274 & 275] 2)R.Ciusa & D.Oreste,Gazz **78**, 57-60(1948) & CA **42**,6761(1948)

*2,4-Dinitrobenzene-1-diazonium Hydroxide*, $(O_2N)_2C_6H_3.N_2.OH$; mw 212.12, N 26.42%. Many of its salts and other derivs have been prepd but their expl props were not reported

*Ref*: Beil **16**,(358) & [278]

**2,4,6-Trinitrobenzene-1-diazonium Hydroxide**, $(O_2N)_3C_6H_2.N_2.OH$; mw 257.12, N 27.24%. Some salts were prepd but their expl props were not reported

*Ref*: Beil **16**, [278]

**Benzene-bis-diazonium Hydroxide**, $C_6H_4[N(:N)-$

OH]$_2$; mw 166.14, N 33.73%. Salts of both the 1,3- and 1,4-isomers have been prepd, some of which are expl. Salts of *Benzene-bis-(1,3-diazonium hydroxide): Chloride*, $C_6H_4(N_2.Cl)_2$, yel crysts, very expl; *Sulfate*, $C_6H_4(N_2.O.SO_3H)_2$, ndls, expl on heating; *Chloroaurate*, $C_6H_4(N_2Cl)_2$-+2$AuCl_3$, yel ndls, expl; *Chloroplatinate*, $C_6H_4$-$(N_2.Cl)_2$+$PtCl_4$, yel lfts, expl violently on heating(Ref 1). Salts of *Benzene-bis-(1,4-diazonium hydroxide)Chloride*, yel ndls, very unstable expl compd; *Sulfate*, ndls, expl on heating; *Perchlorate*, lt-yel ndls, extremely expl; *Chloroplatinate*, yel cryst ppt, expl and *Borofluoride*, brn-yel cryst, dec ca 186°(Ref 2)

*Refs*: 1)Beil **16**,514 & [285] 2)Beil **16**,515,(326) & [285]

**Benzenediazonium Nitrate**(Diazobenzene Nitrate) (called Aniline Fulminante in Fr), $C_6H_5.N_2.O$-$NO_2$; mw 167.12, N 25.15%; col ndls(from alc by pptn with eth), mp- expl ca 90°, d 1.37, $Q^v_c$ 78.4 kcal/mol, $Q^v_e$ 114.8kcal/mol, $Q^v_f$ -47.4 kal/mole; v sol in w; sl sol in alc; nearly insol in eth,benz or chlf. Its toxicity is unknown but its expln hazard is severe when slightly shocked or exposed to heat(Ref 10). Berthelot & Vieille(Ref 2) prepd the compd by passing nitrous gas into a cooled aq soln of aniline nitrate, dilutg with an equal vol of alc and pptg by the addn of excess ether. Other methods of prepn are given in Refs 1,8 & 9

Benzenediazonium nitrate detonates easily by impact or friction. Some of its expl and other props are given by Wöhler & Matter(Ref 4): *Covolume* of 1g, 0.815 vs 0.315 for MF; *Explosion Temperature*, 90° vs 190° for MF; *Heat of Combustion*, 678kcal/kg vs 403kcal/kg for MF; *Initiating Action*, does not initiate HE's such as PA; *Lead Plate Test*, 1g incompletely punctured a 3mm lead plate; MF under the same conditions punctured the plate completely; *Trauzl Test*, expansion for a 2.0g sample at d 1.45 was 43.1ml vs 25.6 for MF at d 3.37

*Uses:* This compd has been proposed as a subst for MF in detonators and for use in some ignition compns. Mixed with LA, it was patented for use in detong revets(Ref 7)

*Refs*: Beil **16**,432 & [352] 2)M.Berthelot & P. Vieille,MP **1**,99-108(1882-3) 3)Daniel(1902),28 & 462 4)L.Wöhler & O.Matter,SS **2**,204,245-7 & 266-9(1907) 5)Marshall **2**(1917),512 6)W.Arthur,IEC **9**,395(1917) 7)Dynamit-AG,BritP 528299(1940) & CA **35**,7716(1941) 8)Davis(1943),442 9)F.H.Westheimer et al, JACS **69**,773(1947) & CA **41**,4783 (1947) 10)Sax(1957),546

**2,4-Dinitrobenzenediazonium Nitrate**(2,4-Dinitrodiazobenzene Nitrate),$(O_2N)_2C_6H_3.N(:N).O.NO_2$; mw 257.12, N 27.24%; lustrous yel plates, mp- expl violently when heated. Was prepd by treating 2,4-dinitroaniline with dil nitric acid and N oxides under cooling(Ref 2) or by treating 2,4-dinitroaniline with K pyrosulfate in highly concd nitric acid under cooling(Ref 3)

*Refs*: 1)Beil **16**,493 2)T.Curtius & G.M.Dedichen, JPrChem **50**,268(1894) & JCS **68** I,30(1895) 3)O. N.Witt,Ber **42**,2957(1908)

**Benzenediazonium Oxalate**(Diazobenzene Oxalate), $C_6H_5.N_2.OCO.COOH$; mw 194.14, N 14.43%; col ndls(from MeOH by pptn with eth), mp- expl on heating; sol in AcOH or MeOH; sl sol in alc; insol in eth. Can be prepd, according to Knoevenagel (Ref 2), by treating aniline oxalate with amyl nitrate in abs alc at ca 0°. This compd expl violently on impact

*Refs*: 1)Beil **16**,432 2)E.Knoevenagel,Ber **28**, 2059(1895)

**Benzendiazonium Perchlorate and Derivatives**

**Benzenediazonium Perchlorate**(Diazobenzene Perchlorate), $C_6H_5.N_2.OClO_3$; mw 204.57, N 13.69%; col ndls, mp- expl; sol in w. It can be prepd by mixing a 10% aq soln of benzenediazonium chloride with a dil aq soln of perchloric acid (Refs 2 & 3) or by other methods(Refs 1,4 & 5). This compd, when dry, is a violent expl, extremely sensitive to the slightest shock. Expln occurs sometimes with it in a moist condition and for this reason it has not found practical application. However, Herz(Ref 4) patented its use in detonators

*Refs*: 1)Beil **16**,431 2)D.Vorländer,Ber **39**,2714 (1906) 3)K.A.Hoffmann & A.Arnoldi,Ber **39**,3147 (1906) 4)E.Herz,BritP 27198(1912) & CA **8**,1672 (1914) 5)A.Stettbacher,SS **11**,147(1916)

**m-Nitrobenzenediazonium Perchlorate** [(1-Diazo-3-nitrobenzene)-Perchlorate] (called Diazo-m-nitranilinperchlorat or *Blitzpulver* in Ger), $O_2N.C_6H_4$-$.N_2.OClO_3$; mw 249.57, N 16.84%; crysts, mp-expl ca 154°. This compd was first prepd by Herz (Ref 2) from m-nitroaniline, perchloric acid and Na nitrite. Davis(Ref 4) gives a detailed method of prepn. Also see Stettbacher(Ref 5)

It expl on heating, impact or by friction. It was patented as a primary or initiating expl to replace MF and reported to have been used in Germany as a primary chge in compd detonators, with nitro-

mannite(or other HE) as a base chge. According to Colver(Ref 3), a detonator contg 0.015g nitrobenzenediazonium perchlorate will expl PA, while 0.1 to 0.3g will completely deton an AN expl

*Refs*: 1)Beil - not found 2)E.Herz,GerP 258679 (1911) & CA **7**,2687(1913); BritP 27198(1912) & CA **8**,1672(1914) and FrP 450897(1912) & JSCI **32**,627(1913) 3)Colver(1918),738 4)Davis(1943), 442-3 5)Stettbacher(1948),99

**Benzenediazonium Picrate**(Diazobenzene Picrate), $C_6H_5.N_2.O.C_6H_2(NO_2)_3$; mw 333.22, N 21.02%; yel crysts, mp- expl at 85°; insol in w, eth or benz. Can be prepd by mixing aq solns of benzenediazonium nitrate and sodium picrate. Other methods of prepn and props are described by Huisgen & Horeld(Refs 2 & 3)

*Refs*: 1)Beil **16**,432 & (353) 2)R.Huisgen & G. Horeld,Ann **562**,137(1949) & CA **46**,8622(1952) 3)R.Huisgen,Ann **573**,163(1951) & CA **46**,8622 (1952)

**Benzenediazonium Sulfate**(Diazobenzene Sulfate), $C_6H_5.N_2.O.SO_3H$; mw 202.18, N 13.86%; wh hygr prisms(from aq alc by pptn with eth), mp- expl ca 100°; v sol in w; sl sol in dil alc; insol in eth. Can be prepd by treating, in the cold, aniline sulfate in a mixt of glac AcOH with the calcd amt of sulfuric acid and a sl excess of amyl nitrite. This compd expl from heat or shock

*Refs*: 1)Beil **16**,431-2 2)P.Griess,Ann **137**,48 (1866) & JCS **20**,41-3(1867) 3)E.Knoevenagel, Ber **23**,2996(1890)

**Benzenediazonium Sulfocyanate**(Diazobenzene Sulfocyanate or Diazobenzene Thiocyanate), $C_6H_5.N_2.SCN$; mw 163.19, N 25.75%; yel solid, mp- expl on heating or impact. Can be prepd by mixing an ice cold soln of benzenediazonium chloride in abs alc with the calcd amt of K sulfocyante. This is a very powerful, sensitive and unstable expl

*Refs*: 1)Beil **16**,432 2)A.Hantzsch & B.Hirsch, Ber **29**,948(1896)

**Benzenediazonium (or Diazobenzene) Sulfonic Acid and Derivatives**

**Benzenediazonium Sulfonic Acid**(Diazobenzene Sulfonic Acid), $N_2.C_6H_4.O_2.S$ (O); mw 184.17, N 15.15%. Three isomers are known. They are all expl and can be prepd by diazotizing the corresponding aniline sulfonic acid: *Ortho or 2-Diazo-*, col cryst solid, expl weakly on heating; sl sol in w; decomp in hot w or hot alc; *Meta or 3-Diazo-*, col prisms(from w), expl even by touching and on heating; decomp in w at 60° or in hot alc; and *Para or 4-Diazo-*, col ndls(from w); expl in dry state by heating(fl p 150°, Ref 2), on impact or friction; sol in hot w or dil alkalies; decomp in hot alc

*Refs*: 1)Beil **16**,557,559,561 & (369) 2)Dynamit-AG,BritP 528299(1940) & CA **35**,7716(1941) 3)Sax(1957),546

**2-Azido-4-diazobenzenesulfonic Acid**(called 2-Azido-4-diazo-benzol-sulfonsäure-(1) in Ger), $N_2.C_6H_3(N_3).O_2.S$ (O); mw 225.20, N 31.06%; orn-red crysts, mp- very expl. Can be prepd by passing N oxides through an alc suspension of 2-hydrazino-4-amino-1-benzenesulfonic acid

*Refs*: 1)Beil **16**,565 2)H.Limpricht,Ber **21**, 3414(1888)

**p-Nitrobenzenediazonium-2,1-naphtholsulfonate**, $O_2N.C_6H_4.N_2.O.C_{10}H_6SO_3H$; mw 373.56, N 11.31%; lt orn crysts(from w at 40°), mp- dec 90-100°; expl on rapid heating. Can be prepd by reacting p-nitrobenzenediazonium chloride with 2,1-naphtholsulfonic acid in HCl. Warming the aq soln at 60° gives the diazooxy compd, while at 70° para red dye is formed. The diazooxy compd, $O_2N.C_6H_4.N_2.O.C_{10}H_5.(SO_3Na)$-(1,2), pale orn-brn, very unstable, is best prepd from the above reactants in $NaHCO_3$,pptd by sodium chloride

*Refs*: 1)Beil- not found 2)H.T.Bucherer & C. Tama,JPraktChem **127**,41(1930) & CA **24**,4280 (1930)

**Benzenediazonium Tetrachloroiodide**(Diazobenzene Tetrachloroiodide), $C_6H_5.N_2.ICl_4$; mw373.87, N 7.50%; bright yel prisms(from dil soln of iodine trichloride in concd HCl), mp 88°(dec), sometimes explg. Was prepd by treating benzenediazonium chloride with a cooled soln of tetrachloroiodic acid($HICl_4$). This compd is stable and can be kept indefinitely if sealed in glass or kept in a desiccator filled with chlorine

*Refs:* 1)Beil **16**, [268] 2)F.D.Chattaway et al, JCS **125** II,1980-2(1924)

**Benzenediazonium Tribromide** (Diazobenzene Tribromide), $C_6H_5.N_2.Br_3$; mw 264.95, N 10.58%; orn-red ndls, mp 63.5° (dec), expl weakly on heating; diffc sol in cold alc; insol in w or eth. Can be prepd by treating a benzenediazonium chloride soln with an aq K bromide soln and by reacting bromine in a hydrobromic acid soln with a soln of benzenediazonium nitrate or sulfate. The dry comp is stable but in a humid atm it dec into 2,-4,6-tribromophenol. It rapidly dec in the presence of alc

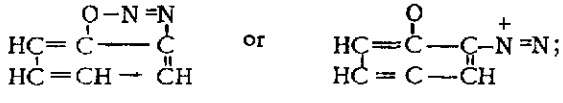
*Refs*: 1)Beil **16**,431 2)F.D.Chattaway, JCS **95**, 865(1909)

**Benzenediazonium Salt of Trinitromethane**, $C_6H_5$-N:N.O.NO:$C(NO_2)_2$; mw 255.15, N 27.45%; yel prisms(from acet+eth), mp- expl violently ca 40°; sol in acet or hot w; diffc sol in cold w; almost insol in alc, eth, chlf or benz. Can be prepd by reacting in the cold aq solns of benzenediazonium acetate and K trinitromethane. This compd is fairly stable in the pure state, but very unstable when impure. It expl when heated or on impact

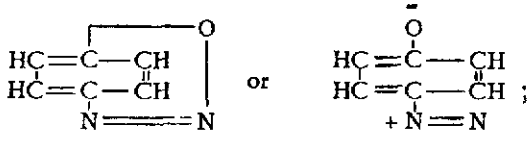
*Refs*: 1)Beil **16**,(352-3) 2)G.Ponzio,Gazz **45** II,21(1915)

**Benzenediazoöxide and Derivatives**

*Benzenediazoöxide or Benzoxadiazole* (called Benzooxdiazol in Ger),



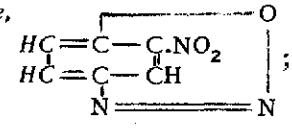
(in CA called *1,2,3-Benzoxadiazole or Benzene-2-diazo-1-oxide;* in Beil called Benzo-1,2,3-oxdiazole)



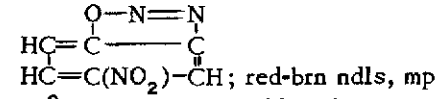
(called *Benzene-4-diazo-1-oxide* by Morgan & Porter), mw 120.11, N 23.33%. These compds are considered to be derived from diazophenols and info available suggests that they have not hitherto been isolated. The constitution and structure of the diazoöxides has been the subject for considerable discussion (Ref 1) and they are of great industrial interest due to the expl nature of their derivs, and the azo dyes and valuable "lakes" which other derivs form

*Refs*: 1)Beil **16**,520 2)Beil **27**,567

**Mononitrobenzenediazoöxide**, $C_6H_3N_3O_3$, mw 165.11, N 25.45%. The following isomers are reported by Morgan & Porter(Ref 6): *2-Nitrobenzene-4-diazo-1-oxide,*



yel lfts(from hot w), mp- exploded with considerable violence at 168°; mod sol in acet or et acet; sl sol in methyl or ethyl alcs; insol in benz or chlf. Was prepd by diazotization of 2-nitro-4-aminophenol with $NaNO_2$ in cold dil $H_2SO_4$ or by diazotization of 4-chloro-3-nitroaniline in mod concd HCl or sulfuric acid, followed by partial neutralization(Ref 1); *3-Nitrobenzene-4-diazo-1-oxide*, brn-red ndls(from et acet), mp- expl at 119°; readily sol in warm w to a pale yel soln; mod sol in alc, acet or et acet; diffc sol in benz; insol in eth. Was prepd by treating 3-nitro-4-aminophenol with ethyl nitrite in glac AcOH or by treating an eth-alc soln of 3-nitro-4-aminophenol with nitrous oxide fumes(Ref 2); *4-Nitrobenzene-2-diazo-1-oxide,*



red-brn ndls, mp -expl ca 118°; easily sol in cold HCl or $H_2SO_4$; sol in alc; diffc sol in w or eth. Was first prepd by Griess(Ref 5) by treating an ether soln of 4-nitro-2-aminophenol with $HNO_3$(Ref 4); *5-Nitrobenzene-2-diazo-1-oxide,* red ndls(from acet or et acet); mp- darkened at 95°, became black at 105° and exploded violently at 111°; mod sol in hot w or alc, giving a yel soln; sol in acet or et acet, giving an orn-red soln; diffc sol in eth or benz. Was prepd by treating 5-nitro-2-aminophenol with Na nitrite in dil HCl or with ethyl nitrite in glac AcOH(Ref 3)

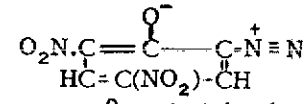
The thermal decompn of these nitrobenzenediazoöxides, in a vacuum, has been studied betw 50 and 120° by Vaughan & Phillips(Ref 7). Under these conditions, mononitrobenzene-2-diazo-1-oxides appear to be less stable than the corresponding 4-diazo-1-oxides

*Refs*: 1)Beil **16**,(364) & [289] (describes this compd as 2-nitro-4-diazophenol) 2)Beil **16**,(364) (describes this compd as 3-nitro-4-diazophenol) 3)Beil **16**, (363)(describes this compd as 5-nitro-2-diazophenol) 4)Beil **16**,524, (363) & [287] (describes this compd as 4-nitro-2-diazophenol) 5)P.Griess,Ann **113**,212(1860) 6)G.T.Morgan & J.W.Porter,JCS **107** I,651-6(1915) & CA **9**,2061-2 (1915) 7)J.Vaughan & L.Phillips,JCS **1947**,1560

& CA **42**,3571(1948)

**DINITROBENZENEDIAZOÖXIDE or DIAZODINITROPHENOL** (Called Dinitrodiazophenol or Dinitro-chinon-diazid in Ger), $C_6H_2N_4O_5$, mw 210.11, N 26.67%, OB to $CO_2$ -61.0%. Two isomers are described in the literature:

**4,6-Dinitrobenzene-2-diazo-1-oxide** or *5,7-Dinitro-1,2,3-benzoxadiazole*, (4,6-Dinitro-2-diazophenol or 3,5-Dinitro-1,2-benzoquinone-1-diazide), commonly known as **Diazodinitrophenol (DADNPh or DDNP) or Dinol**

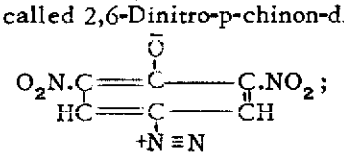


yel lfts(from alc), mp 157-8°(expl violently at higher temps); apparent d 0.27, cryst d at 25° 1.65, pressed d 0.86 at 3400psi(239kg/cm²)(Refs 9 & 10), pressed d 1.14 at 3000psi(Ref 25). Solubilities in g per 100g solvent at 50°: 2.45 in ethyl acetate, 2.43 ethanol, 1.25 methanol, 0.73 ethylene dichloride, 0.23 benz, 0.15 toluene & 0.11 chlf; 0.08g in ether at 30°(Refs 9 & 25); mod sol in glac AcOH; nearly insol in w, $CCl_4$, $CS_2$ & petr ether. Was first prepd by Griess(Ref 3) by diazotization of 4,6-dinitro-2-aminophenol(picramic acid) with Na nitrite in dil hydrochloric or sulfuric acid. Other methods of prepn are listed in Ref 1. Davis(Ref 9) described a lab method. Patents for industrial prepns were granted to Hancock & Pritchett(Ref 6), Alexander(Ref 7), and Babock(Ref 8)

**Explosive and Other Properties of DADNPh:** *Activation Energy* 55kcal/mol(Ref 18); *Behavior Towards Flame* - ignites and burns like NC, even in quantities of several grams(Ref 9); *Brisance*, by Sand Test - 95 & 99% TNT(Ref 25) & 200%MF (Ref 10); *Brisance*, by Lead Block Compression Test - 71% TNT(Ref 10); *Burning Rate* 2.15cm/sec at atm, pressure, for sample in the form of compressed cylinders(Ref 12); *Compatibility* - incompatible with LA(Ref 10); *Dead-pressing* - not dead pressed at 130000psi(9139 kg/cm²)(Refs 9 & 10); *Electrostatic Discharge, Sensitivity to* -0.012 joules(Ref 25); *Explosion Temperature* -165°(Ref 17); 195° in 5secs(Ref 25); *Friction Sensitivity* - about the same as that of LA and less sensitive than MF(Ref 9); *Gas Volume*, 865 l/kg(Ref 25); *Heat of Combustion* 2243cal/g(Ref 25); *Heat of Explosion*, 172.2kcal/mol(Ref 10); 820cal/g(Ref 25); *Heat Test, 100°*,% Loss:2.10 in 1st 48hrs, 2.20 in 2nd 48hrs; no expln in 100hrs(Ref 25); *Hygroscopicity*, 0.04% at 30° & 90%RH(Ref 25); *Impact Sensitivity* - less sensitive than MF & LA (Ref 9); FI 18% PA(Ref 10); 4-7" vs 2-4" for MF by PicArsn App with 1 lb wt using 15mg samples (Ref 25); *Power* by Trauzl Test, 97% PA or 110% TNT(Ref 10); *Rate of Detonation*, 4400m/sec at d 0.9, 6600 at d 1.5 and 6900 at d 1.6(Ref 25); *Sensitivity as an Initiator*, min amt of DADNPh required to initiate 0.5g of the following HE's: Tetryl 0.075g, HNDPhA 0.075, PA 0.115 and TNT 0.163. All expls were pressed at 3400psi (Ref 5); *Shock Sensitivity* - initiated by shock at Mach 5.5-6.3(Ref 22); *Stability* - no loss in power after 5mos wet storage; stable to diffused light and to storage at 60°; darkens in direct light(Ref 5); effect of gamma radiation on DADNPh was studied by Rosenwasser(Ref 23)(See also Heat Test, 100° and Vacuum Stability, 100°); *Time Lag Before Initiation by DADNPh* is discussed in Ref 20; *Vacuum Stability, 100°*, 7.6cc/5g/40hrs(Ref 25); and *Volatility* - unaffected in 30 months at 50°

**Uses.** DADNPh is a HE suitable for use as an initiating expl. Its props & suitability as an expl have been studied extensively by Clark(Ref 5), Grant & Tiffany(Ref 11) and reviewed by Ficheroulle & Kovache(Ref 16). Rolland(Ref 14) proposed a compd detonator with PETN as a base chge with a superimposed initiating chge consisting of DADNPh 75 and expl org nitrate(nitromannite, nitrodulcite or nitrostarch) 25%. Schuricht (Ref 19) proposed an ammunition priming composition as follows: Complex salt(LSt, basic LSt or lead hypophosphite) 48.5, Tetracene 5.0, DADNPh 7.0, Pb nitrate 19.0, ground glass 19.0, gum arabic 1.0 & Aerogel 0.5%. Tsukii & Kichuchi(Ref 21) patented an expl compn suitable for riveting and constg of DADNPh 60 & Tetracene 40% or DADNPh 60, Tetracene 20 & RDX(or NGu) 20%, with $KClO_3$ or $KNO_3$ added as an oxidg agent

**2,6-Dinitrobenzene-4-diazo-1-oxide or 2,6-Dinitro-4-diazophenol** [called 2,6-Dinitro-p-chinon-diazid-(4) in Ger],



flakes(from w), mp- expl violently ca 190°. Can be prepd by diazotizing 2,6-dinitro-4-aminophenol or its methyl ether by $NaNO_2$ in acid solns(Refs 2 & 4). The thermal decompn of these dinitrobenzenediazoöxides, in a vacuum, has been studied betw 50 & 120° by Vaughan & Phillips(Ref 15).

Under these conditions, 4,6-dinitrobenzene-2-diazo-1-oxide appears to be less stable than the 2,6-dinitrobenzene-4-diazo-1-oxide

*Analytical.* Schaefer & Becker(Ref 13) developed a new method for detg diazo N in stable diazo compds. This method consists in treating a sample with a large excess of Ti chloride and measuring the amt of evolved gas. A method for detg nitro N in stable diazo compds, provided the diazo N is known, consists of slowly adding a soln of the sample in acetic acid, with swirling, to a measured vol of Ti chloride

*Refs:* 1)Beil **16**,524 & [287] 2)Beil **16**,531 3)P.Griess,Ann **113**,205(1860) 4)R.Meldola & F.G.Stephens, JCS **87**,1204-5(1905) 5)L.V.Clark, IEC **25**,663-9(1933) & CA **27**,3611(1933) 6)R.S. Hancock & L.C.Pritchett,USP 1952591(1934) & CA **28**,3426(1934) 7)H.B.Alexander,USP 2103926 (1938) & CA **32**,1714(1938) 8)L.W.Babock,USP 2155579(1939) & CA **33**,5869(1939) 9)Davis(1943) 443-6 10)Blatt,OSRD **2014**(1944) 11)R.L.Grant & J.E.Tiffany,IEC **37**,661-6(1945) & CA **39**,3671 (1945) 12)A.F.Belyaev & A.E.Belyaeva,Dokl AkadN **52**,503-5(1946) & CA **41**,4310(1947) 13)W. E.Shaefer & W.W.Becker,AnalChem **19**,307-10 & CA **41**,4062(1947) 14)G.F.Roland,USP 2422043 (1947) & CA **41**,5725(1947) 15)J.Vaughan & L. Phillips,JCS **1947**,1560-5 & CA **42**,3571(1948) 16)H.Ficheroulle & A.Kovache,MP **31**,7-27(1949) & CA **46**,1186-7(1952) 17)H.Henkin & R.McGill, IEC **44**,1391-5(1952) & CA **46**,8857-8(1952) 18)A. Suzuki,JIndExplSocJapan **14**,142-63(1953) & CA **49**,11281(1955) 19)A.G.Schuricht,USP 2662818 (1953) & CA **48**,3692(1954) 20)H.Sudo,JIndExplSocJapan **15**,277-81(1954) & CA **49**,11283(1955) 21)T.Tsukii & S.Kichuchi,JapP 4443(1954) & CA **49**,10628(1955) 22)W.A.Gey & H.L.Bennet,JChemPhys **23**,1979-80(1955) & CA **50**,2174(1956) 23)H. Rosenwasser,OakRidgeNatlLab(ORNL)Rept **1720** (1955) & CA **50**,14229(1956) 24)Sax(1957),547 25)PATR **1740**,Rev 1(1958),101-5

**2,3,6-Trinitrobenzene-4-diazo-1-oxide or 2,3,6-Trinitro-4-diazophenol,** $C_6HO_7N_5$; mw 255.11, N 27.45%; ocher col prisms(from glac AcOH), mp- expl violently; decompd by most solvs, and tends to retain those which do not react with it chemically; decompd by alkalies or carbonates. Was prepd by Meldola & Hay(Ref 2) by diazotization of 2,3,6-trinitro-4-aminophenol with $NaNO_2$ in acid soln. Because of its high sensitivity, the props of this compd were not detd

*Refs:* 1)Beil **16**,531 2)R.Meldola & J.G.Hay, JCS **95**,1383-4(1909)

**3-[(1-Benzene-4-dimethylamino)-azo]-s(1,2,4)-triazole,5-Azido.** See under Dimethylaminobenzeneazotriazole and R.Stollé & W.Dietrich,JPraktChem **139**,202(1934) & CA **28**,2714(1934)

**Benzenedioxime.** This is a misnomer for Benzaldehydeoxime

### Benzenehexamethanol and Derivatives

*Benzenehexamethanol,*

$HO.H_2C.C=C(CH_2OH)-C(CH_2OH)$
$HO.H_2C.C=C(CH_2OH)-C(CH_2OH)$. This compd, prepd by Backer(Ref 2) and called Hexahydroxymethyl-benzene, is a parent compd of its hexanitrate

*Refs* 1)Beil- not found 2)H.J.Backer,Rec **54**, 834(1935) & CA **30**,1367(1936)

**Benzenehexamethanol Hexanitrate** (called Hexanitrate de Hexa-hydroxyméthyl-benzène by Backer), $C_{12}H_{12}N_6O_{18}$; mw 528.14, N 15.91%, OB to $CO_2$ -36.3%. Col crysts(from acet), mp 176.4° with decompn; expl on further heating or on impact(Ref 3). Its $Q_c$, $Q_e$, power and temp of expln are given in conf Ref 3. Was prepd by heating benzenehexamethanol in abs nitric acid until complete dissolution, followed by cooling

*Refs:* 1)Beil- not found 2)H.J.Backer,Rec **54**, 834-5(1935) & CA **30**,1367(1936) 3)ADL Punch Cards(1954)(Conf)(not used as a source of info)

### Benzenesulfenamide and Derivatives

*Benzenesulfenamide* (called Benzolsulfensäureamid in Ger), $C_6H_5.S.NH_2$; seems to exist only in the form of derivs, such as:

*Mononitrobenzenesulfenamides,* $(O_2N)C_6H_4.S.NH_2$. Its 2-isomer melts at 120-4°, while the 4-isomer melts at 99-103°

*Refs:* 1)Beil- not found 2)R.A.Coleman,USP 2,404,695(1946) & CA **41**,154(1947)

**2,4-Dinitrobenzenesulfenamide,** $(O_2N)_2C_6H_3.S.NH_2$; mw 215.24, N 19.50%. Yel crysts(from ethanol), mp 119.0-205°. Can be prepd by cleavage of 4-benzylthio-1,3-dinitrobenzene with chlorine. Its expl props were not detd

*Refs:* 1)Beil- not found 2)R.H.Baker et al,JACS **68**,2639(1946) & CA **41**,2058(1947) 3)N.V.Khromov-Borisov & M.B.Kolesova,ZhObshchKhim **25**,361-5 & 380(1955) & CA **50**,2466(1956)

### Benzenesulfenic Acid and Derivatives

*Benzenesulfenic Acid or Phenylsulfohydroxide*

(Called Benzolsulfensäure in Ger), $C_6H_5.SOH$; seems to exist only in the form of its derivs, such as:

*Benzenesulfenyl Chloride or Phenylsulfochloride.* (Benzolsulfensäure-chlorid in Ger), $C_6H_5.SCl$. Red liq which smokes in the air; bp 73-5° at 9mm; dec when distilled under atm pressure. Its prepn & props are described in Refs 1,2 & 3. It was reported (Ref 4) that a glass container with benzenesulfenylchloride exploded at Shell Houston Research Laboratory after standing undisturbed for several months

*Refs*: 1)Beil **6**, [295] 2)H.Lecher & F.Holschneider,Ber **57**,757(1924) 3)N.Kharash et al, ChemRevs **39**,279(1946) 4)Anon,C&EN **35**,No 47, p 57(1957)

**Mononitrobenzenesulfenylchlorides**, $O_2N.C_6H_4.SCl$. The following isomers are described in the literature: *2-Nitrobenzenesulfenylchloride*. Yel ndls (from benz); mp 75°, expl on further heating. Easily sol in benz, AcOH & chlf; diffc sol in eth, $CCl_4$ & petr eth. Can be prepd by chlorination of 2,2'-dinitrodiphenyl-disulfide(Refs 1,3,6,7 & 8). The *anhydride* of the disulfide, called o.o'-Dinitrophenyl-schwefeloxyd by Zincke, $O_2N.C_6H_4.S.O.S.C_6H_4.NO_2$, expl at temps higher than its mp 92-3°(Refs 1 & 2); *3-Nitrobenzenesulfenylchloride* was prepd by chlorination of 3,3'-dinitrodiphenyldisulfide; no props are given(Ref 5); and *4-Nitrobenzenesulfenylchloride*, yel scales(from hexane), mp ~52°; was prepd by chlorination of 4,4'-dinitrodiphenyldisulfide(Refs 2,4 & 8). The *anhydride* of the disulfide, called p.p'-Dinitrophenyl-schwefeloxyd by Zincke, yel lfts(from benzene), dec ca 160° and expl mildly(Refs 2 & 4)

*Refs*: 1)Beil **6**,(157) & [308] 2)Beil **6**,(160) 3)T.Zincke & F.Farr,Ann **391**,63 & 67(1912) 4)T. Zincke & S.Lenhardt,Ann **400**,9-12(1913) 5)N.E. Foss et al,JACS **60**,2729(1938) 6)J.H.Billman & E.O'Mahony,JACS **61**,2340-1(1939) 7)OrgSynth-CollVol **2**(1943),455 8)N.Kharash et al, ChemRevs **39**,281(1946)

**2,4-Dinitrobenzenesulfenylchloride**, $(O_2N)_2C_6H_3.SCl$; yel crysts, mp 94-6°. Can be prepd by reaction of chlorine with a suspension of 2,4-dinitrophenyldisulfide in MNB(Refs 2 & 3). It is a dangerous expl and heating it above 90-100° should be avoided(Ref 4)

*Refs*: 1)Beil- not found 2)J.H.Bilman et al,JACS **63**,1920-1(1914) 3)N.Kharash et al,JACS **69**,1613-14(1947) & CA **41**,6217(1947) 4)N.Kharash,JACS **72**,3322-3(1950) & CA **44**,10673(1950)(Expln hazard in the prepn and use of 2,4-dinitrobenzenesulfenyl chloride) 5)N.Kharash et al,JACS **77**, 931-4(1955) & CA **50**,1651-2(1956)(Hydrolysis of 2,4-dinitrobenzenesulfenylchloride)

**Benzenesulfenylchloride.** See above under Benzenesulfenic Acid and Derivatives

### Benzenesulfinic Acid and Derivatives

*Benzenesulfinic Acid* (called Benzolsulfinsäure in Ger), $C_6H_5.SO_2H$; mw 142.18, crysts, mp 83-4°, is described in Ref 1

Its *mononitrocompounds* (2-,3- and 4-isomers) and their salts are described in Ref 2

Davies et al(Ref 3) claimed to have prepd *2,4-dinitrobenzenesulfinic acid*, $(O_2N)_2C_6H_3.SO_2H$, wh tufts, mp 196°, by heating 2,4-dinitrobenzenesulfonylhydrazide with aq hydrazine and dil HCl and pptg the product by addn of concd HCl. Bradbury & Smith(Ref 4) attempted the same method of prepn and obtd the sulfonyl hydrazide, $C_6H_6N_4O_6S$ which, when crystd from dioxane-water at 0°, decompd violently at 113°. On warming the sulfonylhydrazide with HCl at 80°, filtering the insol matter and acidifying with concd HCl, octahedral crysts of the hydrazine dichloride(mp 197°) were pptd

No description of higher nitrocompds could be found in the literature (See also Benzenesulfenic and Benzenesulfonic Acids and Derivatives)

*Refs*: 1)Beil **11**,2-6,(3) & [3-4] 2)Beil **11**,8,(4) & [5] 3)W.Davies et al,JCS **1931**,626 & CA **25**, 2702(1931) 4)H.Bradbury & F.J.Smith,JCS **1952**, 2943 & CA **47**,1082(1953)

### Benzenesulfonic Acid and Derivatives

*Benzenesulfonic Acid* (called Benzolsulfonsäure in Ger), $C_6H_5.SO_3H$; mw 158.18; solid, when anhyd, mp 55-6°. It forms numerous salts and other derivs, some of which are expl. The prepn and props are given in Beil **11**,26-9,(18-20) & [9-11]. This compd can cause serious local toxicity to skin and mucous membranes, as reported by Sax (1957),p 347

**Benzenesulfonyl Azide** (called Benzolsulfonsäureazid in Ger), $C_6H_5.SO_2.N_3$; mw 183.19, N 22.94%; yel oil, mp expl on heating; easily sol in alc, eth or chlf. Can be prepd from benzenesulfonyl hydrazide, Na nitrite and AcOH(Refs 1 & 2) or by treating benzenesulfonyl chloride with Na azide(Ref 3)

*Refs*: 1)Beil **11**,53 2)T.Curtius et al,JPraktChem **58**,174(1898); **106**,72(1923) and **112**,92(1926) 3)T.

Curtius & J.Rissom,JPraktChem **125**,312(1930) & CA **24**,3228(1930)

**m-Benzenedisulfonyl Diazide,** $C_6H_4(SO_2N_3)_2$; mw 256.21, N 32.81%; mp 82°, expl at higher temp. Can be prepd by treating m-benzenedisulfonyl dichloride with Na azide in alc

*Refs*: 1)Beil- not found 2)T.Curtius & H.Meier, JPraktChem **125**,358(1930) & CA **24**,3229(1930)

**Azidobenzenesulfonic Acid,** $N_3.C_6H_4.SO_3H$; mw 199.19, N 21.09%. The *2-Azido deriv* is not described in Beil but the *4-Nitro-2-azido deriv*, $N_3C_6H_3(NO_2).SO_3H$, is listed; the *Potassium salt*, $KC_6H_3N_4O_5S$, lt-brn lfts, of which,expls ca 130° (Ref 1,p 81 & Ref 3,p 3413). The *3-Azido deriv*, deliq ndls, forms a *Barium salt*, $Ba(C_6H_4N_3O_3S)_2$, in the form of ndls which expl ca 130° (Ref 1,p 80 & Ref 3,p 3416). The *4-Azido deriv*, deliq ndls, expl on heating; and also forms a *Barium salt*, fairly sol in hot w(Ref 1,p 80 & [37] and Refs 2 & 3)

*Refs*: 1)Beil **11**,80,81 & [37] 2)P.Griess,Ber **20**,1529(1887) 3)H.Limpricht, Ber **21**,3413 & 3416 (1888) 4)E.Noelting et al,Ber **26**,87 & 91(1893)

**Mononitrobenzenesulfonic Acid,** $O_2N.C_6H_4.SO_3H$; mw 203.18, N 6.90%. Three isomers are described in the literature: *2-Nitro deriv*, v hygr crysts, mp ca 70°; *3-Nitro deriv*, delq lfts; and *4-Nitro deriv*, hygr crysts, mp 95°. Hymas(Ref 2) obtd a *corrosion resistant coating for ferrous surfaces* by treating with phosphoric acid or alkali phosphate soln to which m-nitrobenzene sulfonic acid or certain other org nitro compds have been added

*Refs*: 1)Beil **11**,67-8 & 71(20-21) and [31-33] 2)M.Hymas,USP 2657156(1953) & CA **48**,2557-8 (1954)

**Dinitrobenzenesulfonic Acid,** $(O_2N)_2C_6H_3.SO_3H$; mw 248.22, N 11.35%. The *2,4-Dinitro*, lt yel deliq prisms of the trihydrate which melt at 108° and lose w of crystn at 130°; and *3,5-Dinitro deriv*, deliq cryst, are described in the literature. Their expl props were not investigated

*Ref*: Beil **11**,78-9 & [36]

**2,4,6-Trinitrobenzenesulfonic Acid** (called Pikrylsulfonylsäure in Ger), $(O_2N)_3C_6H_2.SO_3H$; mw 293.17, N 14.33%; crysts of the trihydrate, mp-sinter ca 100° and the anhyd acid melts ca 185°; sol in w, alc & eth; diffc sol in chlf; insol in benz. Can be prepd by heating an alc soln of picryl chloride with an excess of Na sulfite. Its expl props were not investigated. The *Sodium salt*, $(O_2N)_3C_6H_2.SO_3Na+H_2O$; large col transparent crysts, readily sol in w but sparingly sol in alc or eth, loses w of crystn at ordinary temp and may be heated to 300° without decompn; when heated on Pt in an open flame, it explodes

*Refs*: 1)Beil **11**,80 2)C.Willgerodt,JPraktChem **32**,117(1885) & JCS **48** II,1232(1885)

**Benzenesulfonic Acid Azoacetylhydrazide** (called Benzolsulfosäure-azo-acet-hydrazid; 1-[4-Sulfo-phenyl] -4-acetyl-tetrazen-(1); or [4-Sulfo-benzoldiazo] - [β-acetyl-hydrazid] in Ger), $HO_3S.C_6H_4.N{:}N.NH.CO.CH_3$; mw 258.26, N 21.70%. Its *Sodium salt*, $NaC_8H_9N_4O_4S+2H_2O$, wh lustrous cryst, produced from diazobenzenesulfonic acid and acetylhydrazide, explodes when heated. In w, the Na benzenesulfonate salt gives hydrogen azide and Na sulfanilate; NaOH and p-toluenediazonium chloride convert it into hydrogen azide and Na p-toluenediazoaminobenzenesulfonate

*Refs*: 1)Beil **16**,(419) 2)O.Dimroth & G.de Montmollin,Ber **43**,2912-3(1910) & CA **5**,494(1911)

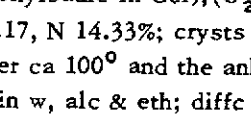
**Benzenesulfonyl Peroxide** (called Dibenzolsulfonyl-peroxyd in Ger), $C_6H_5.SO_2.O.O.O_2S.C_6H_5$; mw 314.34, O 30.6%, col prisms(from alc), mp expl ca 53-4°; readily sol in eth or chlf; diffc sol in alc; insol in w. Can be prepd from benzenesulfonyl chloride and Na peroxide in ice cold w. This compd expl also on impact

*Refs*: 1)Beil **11**,34 2)R.Weinland & H.Lewkowitz,Ber **36**,2702(1903)

**Benzenesulfonyl Sulfuric Acid Peroxide** (called Benzol-sulfonylsulfomonopersäure in Ger), $C_6H_5.SO_2.O.O.SO_3H$; mw 254.25, O 44.1%. Its *Potassium Salt*, $KC_6H_5O_7S_2$, sq prisms(from w), dec on storage and expl mildly when heated

*Ref*: 1)Beil **11**,34 2)R.Willstätter & E.Hauenstein,Ber **42**,1848(1909)

**Benzenesulfonyl-2,5-tolylenediazoimide** [called N-Benzol-sulfonyl-4-diazo-2-methyl-anilin or Toluchinon-benzolsulfonylimid-(1)-diazid-(4) in Ger], $C_6H_5.SO_2.N{:}(CH_3)C_6H_3{:}N_2$ or

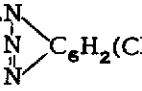


$C_6H_5.SO_2.N$ … $C_6H_3.CH_3$; mw 273.31, N 15.38%;

lt-yel ndls; mp dec explosively at 163°. Was prepd by diazotizing 5-amino-2-benzenesulfaminotoluene with concd HCl, aq Na nitrite and pptg the product by treating the filtrate with Na acetate

*Refs*: 1)Beil **16**,608 2)G.T.Morgan & F.M. Micklethwait,JCS **87**,925-6(1905)

**Benzenesulfonyl-p-xylylene-2,5-diazoimide** (called N-Benzol-sulfonyl-4-diazo-2,5-dimethyl-anilin or p-Xylochinon-benzol-sulfonylimid-diazid in Ger), $C_6H_5.SO_2.N:(CH_3)_2C_6H_2:N_2$ or



$C_6H_2(CH_3)_2$; mw 287.33, N 14.62%; yel ppt; mp-dec explosively at 125-130°. Was prepd by diazotizing 2-amino-5-benzene-sulfamino -p-xylol

*Refs*: 1)Beil **16**,609 2)G.T.Morgan & F.M. Micklethwait,JCS **87**,926-7(1905)

**Benzenetetrazole.** A misnomer for Pyrazopyrazine listed in CA, Subject Index **1907-16**,p 4130

### Benzenethiol and Derivatives

*Benzenethiol; Phenylmercaptan or Thiophenol* (Called Sulfhydrylbenzol or Mercaptobenzol in Ger), $C_6H_5.SH$; liq, bp 168.3°, is described in Beil **6**,294,(142) & [284]. Forms numerous salts *Mononitrobenzenethiol*,$(O_2N).C_6H_4.SH$. Its 2-isomer is a solid melting at 61°; the 3-isomer is an oil with repulsive odor and the 4-isomer is a solid melting at 77°. They are described in Beil **6**,337-9,(154 & 159) and [303-4 & 308-9]

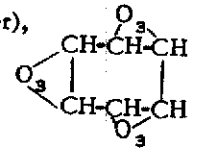
*2,4-Dinitrobenzenethiol*, $(O_2N)_2C_6H_3.SH$; lt-yel crysts, mp 131-2°. Its prepn and other props are in Beil **6**,342,(162) & [315]

**2,4,6-Trinitrobenzenethiol; Picrylmercaptan or 2,4,6-Trinitrothiophenol,** $(O_2N)_3C_6H_2.SH$; mw 245.19, N 17.14%. Small yel crysts, mp ca 114° and expl violently ca 115°. Easily sol in cold w or alc but dec when heated; sol in eth,chlf, acet or benz; nearly insol in $CS_2$ or petr eth. Can be prepd by adding (under cooling) picryl chloride to $K_2S$ dissolved in 90% alc, allowing to stand and then acidifying with a mineral acid

Its *Potassium Salt*, $KC_6N_3H_2O_6S$, reddish-brn ndls, expl violently ca 140° or on impact. Its Ag, Cu, Na and Pb salts are also known(Refs 1 & 2). The Na salt was also prepd by Thomas et al(Ref 3)

*Refs*: 1)Beil **6**,344 & [316] 2)C.Willgerodt, **17**, Ref 353(1884) 3)V.Thomas et al,CR **178**,1289 (1924) & CA **18**,1995(1924)

**Benzene Triozonide,** formerly known as *Ozo-benzene* (called Benzol triozonid in Ger),



mw 222.11, O 64.8%; amor mass, extremely unstable expl, dec in a vac and on exposure to a stream of air; insol in alc, abs eth, chlf, carbon disulfide or ligroin; det violently with warm w, concd sulfuric acid or concd KOH. Even in ice-cold w, the cryst mass expl at the sl touch. Can be obtd by introducing a stream of ozone into pure benz at 5-10°

This extremely unstable expl developes about 25% more energy than NG and its vel of deton is much higher than that of ordinary expls, which gives it exceptionally great disruptive power(Ref 3)

*Refs*: 1)Beil **5**,197 2)C.Harries & V.Weiss,Ber **37**,3431(1904) 3)Anon,SciAmMonthly **1**,144(1920) 4)Tobolsky & Mesrobian(1954),180

**Benzenyloxyhydroxytetrazotic Acid.** See Phenyloxyhydroxytetrazotic Acid

**Benzenyloxytetrazotic Acid.** See Phenyloxytetrazotic Acid

**Benzenyltetrazotsäure.** Old Ger name for 5-phenyl-tetrazole

**Benzfurazan.** See Benzofurazan

**Benzfuroxan.** See Benzofuroxan

### Benzidine and Derivatives

*Benzidine or 4,4'-Diaminobiphenyl* (called 4,4' -Diaminodiphenyl or Benzidin in Ger), $H_2N.C_6H_4.C_6H_4.NH_2$; mw 184.23, N 15.21%; grayish-yel crysts, wh or sl reddish crysts or lfts(depending on solv), mp 127.5-128.5°, bp 402° at 740mm, d 1.250 at 20°. Benzidine is of low order of toxicity but it is suspected to be a possible cause of bladder tumor and when heated to decomp, emits highly toxic fumes(Ref 9). Its other props & prepn are given in Refs 1,4,5,6,7 & 8

It forms various salts and addn compds, the following of which are expl(Ref 1,p 219 & [90] and Ref 2): *Bromate* $C_{12}H_{12}N_2+2HBrO_3$, dec violently on rapid heating; *Chlorate*, $C_{12}H_{12}N_2+2HClO_3$, dec explosively on rapid heating or when heated in the presence of traces of nitric acid; *Perchlorate*, $C_{12}H_{12}N_2+HClO_4$; grayish solid, dec ca 100° and the *Diperchlorate*, dec explosively on rapid heating; *Picrate*, $C_{12}H_{12}N_2+2(C_6H_3N_3O_7)$, yel-grn crysts, expl on rapid heating; *Quinonedichloroimide*, $2(C_{12}H_{12}N_2)+C_6H_4N_2Cl_2$, violet ndls, mp expl ca 121° [Ref

1,p(60) and Ref 1a]

Benzidine has been claimed(Ref 3) to be one of a number of compds suitable as a sensitizer for AN

*Refs*: 1)Beil **13**,214,219,(58) & [90] 1a)A. Knorr,Ber **43**,799(1910); JCS **98** I,324-5(1910) 2)A.E.Kretov,JRussPhysChemSoc **60**,1427(1928) & CA **23**,2117-8(1929) 3)W.O.Snelling & J.A. Wyler,USP 1827675(1932) & CA **26**,601(1932) 4)M.S.Fishbein,VoyennayaKhimia(Russia) **1933**, No 6,p 3-8; ChemZtr **1934** II, & CA **29**, 7077(1935) 5)K.Ino & R.Oda,JSocChemInd(Japan) **46**,552-3 (1943) & CA **42**,6343(1948) 6)USSpec MIL-B-11332 (1951) 7)M.Zisic & V.Premru,KhemZbornik **1951**, 139-42 & CA **48**,10687(1954) 8)T.Maki & K. Obayashi,JSocChemInd(Japan) **55**,108-9(1952) & CA **48**,5836(1954) 9)Sax(1957),347-8

**Benzidine,Alkylated(Nitro Derivatives).** See Vol 1,p A129-L and *Note* under 2,5,3'-Trinitrobenzidine

*Mononitrobenzidine*, $H_2N.C_6H_4.C_6H_3(NO_2).NH_2$; mw 229.23, N 18.33%. The 2-Nitro and 3-Nitro -derivs are described in Beil **13**,235,(67) & [107]

**Dinitrobenzidine**, $H_2N.C_6H_3(NO_2).C_6H_3(NO_2).NH_2$, mw 274.23, N 20.43%. The following isomers are described in the literature: *2,2'-Dinitro-*, yel lfts(from alc), mp 214°(Ref 1) & 200-2°(pptd from acid soln)(Ref 2); *2,3'-Dinitro-*, deep red ndls (from phenol-alc), mp 236° & 243-4(Ref 1); *3,3'-Dinitro-*, crysts(from pyridine+alc), mp 275° or red ndls(from phenol), mp 281-2°(Ref 1 & 278-9° (Ref 3)

Other props & prepn are given in the Refs

*Refs*: 1)Beil **13**,235-6,(67-8) & [108] 2)B.A. Porai-Koshits & M.Bentov,ZhObshKhim **14**,1019 -24(1944) & CA **39**,4599(1945) 3)E.D.Bergman & M.Bentov,JOC **19**,1598(1954) & CA **49**,15765 (1955)

**2,2'-Dinitrobenzidine Perchlorate.** Fishbein(Ref 2) treated 2,2'-dinitrobenzidine with nitrous acid and reacted the resulting diazonium compd with perchloric acid to obtain an expl compd which he called "diazo-2,2'-dinitrobenzidine perchlorate". This prod was claimed to be suitable for use in primary and initiating compositions

*Refs*: 1)Beil- not found 2)M.S.Fishbein,VoyennayaKhimia(Russia) **1933**, No 6,pp 3-8 & CA **29**, 7077(1935)

**2,5,3'-Trinitrobenzidine**, $H_2N.C_6H_3(NO_2).C_6H_2(NO_2)_2.NH_2$; mw 319.23, N 21.94%; dk-red ndls (from phenol +alc), mp 276°. It was isolated by LeFèvre et al(Ref 2) from the hydrolysis prod of the nitration of 2-nitrodiacetylbenzidine through the sulfate. The expl props of this compd were not investigated

*Refs*: 1)Beil **13**, [109] 2)R.J.W.LeFèvre et al, JCS **1927**,2332 & 2338 & CA **22**,69(1928)

*Note*: Higher nitro derivatives of benzidine were not found in Beil or in CA through 1956 but some addnl higher nitro alkylated benzidine derivs which are expl include the following:

**N,N'-Dinitro-N,N'-dimethyl-3,5,3',5',-tetranitrobenzidine**, $[\text{-}C_6H_2(NO_2)_2.N(NO_2).CH_3]_2$; lfts (from fuming nitric acid by careful addn of w), mp expl above 220°(Refs 1,3 & 4)

**N,N'-Dinitro-N,N'-dipropyl-3,5,3',5'-tetranitrobenzidine**, $[\text{-}C_6H_2(NO_2)_2.N(NO_2).CH_2.C_2H_5]_2$; lt yel flts(from concd nitric acid), mp expl ca 213°(Refs 2 & 5). Many other alkylated nitrobenzidine derivs dec on heating

*Refs* 1)Beil **13**,237 2)Beil **13**, [110] 3)P.van Romburgh,Rec **5**,244(1886) 4)K.H.Martens,Ber **19**,2126(1886) 5)G.van Romburgh,Rec **41**,42(1922)

### Benzil and Derivatives

*Benzil; Bibenzoyl; Dibenzoyl; Diphenylglyoxal or Diphenyldiketone*, [called 1,2-(or *α,β*-)-diphenyl-äthan or *α,α'*-Dioxo-dibenzyl in Ger], $C_6H_5.CO.CO.C_6H_5$; mw 210.22; yel prisms(from eth), mp 95°, bp 346-8° (dec), d 1.23 at 15°; $Q_c^v$ 1625kcal/mol(w liq); very sol in benz or eth; sol in alc; v sl sol in w. The toxicity of benzil is unknown but it is used as an insecticide(Ref 6). Its prepn and other props are given in Ref 1 and in others(Refs 1,2,3,4,5 & 7)

*Refs*: 1)Beil **7**,747,(392) & [674] 2)A.Zinn,Ann **34**,188(1840) 3)R.Adams,OrgSynth **1**(1921),25-7 4)H.Gilman,OrgSynth **6**(1926),6-7 5)S.M.McElvain et al,JACS **73**,3810(1951) & CA **46**,6627(1952) 6)Sax(1957),348 7)USSpec MIL-B-565A(1958)

*Mononitrobenzil*, $C_6H_5.CO.CO.C_6H_4.NO_2$, mw 255.22, N 5.49%. The *2-, 3- and 4-Nitro derivs* of benzil are described in Beil **7**,765 & [683]

*Dinitrobenzil*, $C_{14}H_8N_2O_6$, mw 300.22, N 9.33%. Nine isomers of dinitrobenzil, none of which seems to be expl, are described in Beil **7**,766, (396) & [684-6]

*Trinitrobenzil*, $C_{14}H_7N_3O_8$-not found in Beil

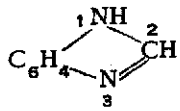
**Tetranitrobenzil**, $C_{14}H_6N_4O_{10}$, mw 390.22, N 14.69%, OB to $CO_2$ -86.1%. Two isomers are described in the literature: *2,4,2',4'-Tetranitro-*

*benzil*, $(O_2N)_2C_6H_3.CO.CO.C_6H_3(NO_2)_2$; pale yel crysts, mp 222-3°; sl sol in glac AcOH or toluene; insol in other ordinary solvs. It was prepd by Blatt & Rytina(Ref 5) by heating a soln of 2,4,2',4'-tetranitrostilbene with strong mixed acid contg nitric acid, sulfuric acid & oleum, and pouring it onto a large quant of ice. When treated with alk hydrogen peroxide the tetranitrobenzil formed 2,4-dinitrophenol(Refs 1 & 5) *3,5,3',5'-Tetranitrobenzil*, pale yel prisms(from AcOH), mp 179°; readily sol in hot AcOH, sl sol in hot alc or benz. It was prepd by heating at 100-10° 3,3'-dinitrobenzil with concd sulfuric acid and nitric acid. It is stable in hot nitric and acetic acids. The expl props of this tetranitro compd are between those of DNT & TNT(Refs 2,3 & 4)
*Refs* 1)Beil- not found 2)Beil **7**, [686] 3)G.H. Cristie & J.Kenner,JCS **1926**,475 & CA **20**,1620 (1926) 4)F.D.Chattaway & E.A.Coulson,JCS **1927**)578 & CA **21**,1983(1927) 5)A.H.Blatt & A.W.Rytina,JACS **72**,405(1950) & CA **45**,1081 (1951)

**2,4,2',4',6'-Pentanitrobenzil**, $(O_2N)_2C_6H_3.CO.CO.C_6H_2(NO_2)_3$; mw 435.22, N 16.09%, OB to $CO_2$ -68.0%; col crysts, turn orn-brn in the light; mp 261°(dec). This compd was prepd by nitration of 2,4,6-trinitrostilbene or 2,4,6,2'-tetranitrostilbene with mixed nitric and sulfuric acids. Pentanitrobenzil is also obtd from 2,4,6,2',4'-pentanitrostilbene under similar conditions. It does not form addn compds with naphthalene or anthracene but thiophthene yields an impure yel prod, mp 220-4°. The pentanitrobenzil is recovered unchanged after boiling with hydroxylamine hydrochloride or o-phenylenediamine in glac AcOH. Its expl props were not detd
*Refs*: 1)Beil- not found 2)F.Challenger & P.H. Clapham,JCS **1948**,1612-4 & CA **43**,1733(1949)

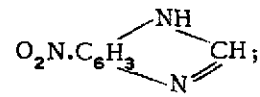
### Benzimidazole and Derivatives

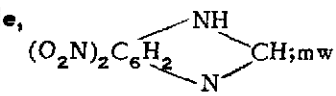
*Benzimidazole; 1,3-Benzodiazole; o-Phenylene-formamidine or Benzoglyoxaline* (called N,N'-Methenyl-o-phenylendiamin or Benzimidazol in Ger),



mw 118.13, N 23.72%. It forms numerous salts and other derivs and addn compds, some of which are expl. Other props & prepn are given in Refs 1 & 2. Its picrate, is described in Ref 3
*Refs*: 1)Beil **23**,131,(35) & [151] 2)A.T.James & E.E.Turner,JCS **1950**,1515 & CA **45**,1116(1951) 3)L.Monti & G.Franchi,Gazz **81**,772(1951) & CA **48**,3976(1954)

**Benzimidazole-diazido-copper Salt**, $[(N_3)_2CuC_7H_6N_2]$, expl weakly at 183-5°, but not under impact
*Refs*: 1)Beil- not found 2)A.Cirulis & M.Straumanis,JPraktChem **162**,307-28(1943) & CA **38**, 1970(1944)

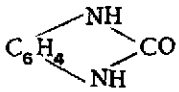
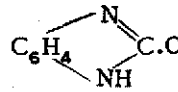
*Mononitrobenzimidazole*,  ; mw 163.13, N 25.76%. The *5(or 6)-Nitro* (Refs 1 & 2) and the *4(or 7)-Nitro* (Refs 1 & 2) derivs are described in the literature. The *Picrate* of 4-nitro-deriv, mp 184-5°, is described in Ref 3
*Refs*: 1)Beil **23**,135 & [154] 2)A.Bamberger & B.Berlé,Ann **273**,340(1893) 3)G.M.van der Want, Rec **67**,48(1948) & CA **42**,5020(1948)

**Dinitrobenzimidazole**,  ; mw 208.13, N 26.92%. The *5,6-Dinitro deriv*, mp 186°, was prepd by Efros(Ref 2) and the *5,7(or 4,6-Dinitro deriv*, mp 239-40°(dec), was prepd by Bahner et al(Ref 3). Their expl props were not detd
*Refs*: 1)Beil- not found 2)L.S.Efros,ZhObshKhim **22**,1008-15(1952) & CA **47**,12366(1953) 3)C.T. Bahner et al,JACS **74**,3689(1952) & CA **48**,5183 (1953)
*Note*: Higher nitro-derivs were not found in Beil or in CA thru 1956

**Benzimidazolol.** Same as Hydroxybenzimidazole

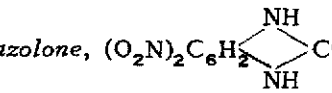
### Benzimidazolone and Derivatives

*Benzimidazolone or o-Phenylene-urea* (called N,N'-o-Phenylen-harnstoff; 2-Oxy-benzimidazol; 2-Oxo-benzimidazolin or Benzimidazolon in Ger),

 or  ; mw 134.13, N 20.89%. It forms numerous salts, some of which are probably expl. Other props & prepn of benzimidazolone are given in Beil 24,116, (240) & [62]

**5,6-Azimino-benzimidazolone.** See 5,6-Azimino-benzimidazole, Vol 1,p A643-R

*Mononitrobenzimidazolone*, $C_7H_5N_3O_3$; mw 179.13, N 23.46%. The *5-Nitro-deriv* is described in Beil **24**,119 & [242]

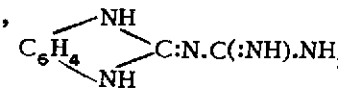
*5,6-Dinitrobenzimidazolone*, 

mw 224.13, N 25.00%; orn-yel ndls(from dil alc), mp above 300°. Other props & prepn are given in Beil **24**, (242)

**Trinitrobenzimidazolone**, $C_7H_3N_5O_7$, mw 269.13, N 26.02%. The *4,5,6-Trinitro* and *5,6,7-Trinitro derivs* were prepd by James & Turner(Ref 2) who studied their antimalarial activity but did not describe their prepn or determine their expl props

*Refs*: 1)Beil- not found 2)A.T.James & E.E. Turner,JCS **1950**,1515 & 1518 & CA **45**,1116(1951)

**Benzimidazolone-guanylimide** [called 1.2-o -Phenylen-biguanid or Benzimidazolyl-(2)-guanidin in Ger],



$C_6H_4$(NH)(NH)C:N.C(:NH).$NH_2$; mw 175.19, N 39.98%; yel lfts of the monohydrate (from w), mp 242° (dec)(Ref 1) or pearly lfts, mp 245°(dec)(Ref 2). Other props and several methods of prepn are given in Refs 1,2 & 3. It forms numerous salts, some of which have weak expl props: *Hydrochloride*, $C_8H_9N_5$+HCl, ndls, dec gradually ca 100°; *Nitrate*, $C_8H_9N_5$+$HNO_3$, wh ndls, mp 216°(dec) and $2C_8H_9N_5$+$5HNO_3$+$3H_2O$, col crysts, mp 178° (dec) and *Picrate*, $C_8H_9N_5$+$C_6H_3(NO_2)_3$.OH, yel ndls, mp 269-70° (Refs 1,2 & 3)

*Refs*: 1)Beil **24**,118 & [62] 2)G.Pellizzari,Gazz **51**, I, 98-9(1921) & CA **15**,3077(1921) 3)F.E.King et al,JCS **1948**,1366 & CA **43**,1404(1949)

**Benzimidezolone-imide.** See Amino-benzimidazole, Vol 1,p A187-R to A188-L

**Benzin, Benzine, Petroleum Benzin or Gasoline.** A mixt of hydrocarbons obtd from the second portion of the fractional distillates, betw 70-90°, of crude petroleum. It is a clear col liq of d 0.640 -0.675; insol in w but miscible with alc, eth, oils and carbon disulfide(Ref 1). This mixt is considered by Sax(Ref 3) to be sl toxic but dangerous when exposed to heat or flame. This mixt should not be confused with benzene or benzene homologues. It can be used as an insecticide and as a solv for some expls. The Germans used it during WW II as one of the fuels(together with O as oxidizer) for propelling the missile of WWII called *V-1*(Ref 4). Benzine with Al dust and liq O as oxidizer was proposed by Stettbacher(Ref 2) as a rocket propellant

*Refs*: 1)Hackh's(1944),p 112 2)A.Stettbacher, Explosivst **1956**,27 & 30 3)Sax(1957),p 348 4)PATR **2510**(PB No 161270)(1958),p Ger 215, under V-1 and V-2 (Propellants; Used in)

**Benzite(Fr).** See 1,3,5-Trinitrobenzene under Benzene

**Benzocarbazole and Derivatives**

*Benzocarbazole*, $C_{16}H_{11}N$. Three isomers are described in Beil **20**,494,495,(179) & [319] and five isomers are given in the CA Decennial Subject Index **41-50**, 1652s(1947-1956)

*Nitrosobenzocarbazole*, $C_{16}H_{10}N.NO$. Two isomers are described in Beil **20**,495 & 496

*Mononitrobenzocarbazole*, $C_{16}H_{10}N_2O_2$. One isoer is described in Beil **20**,(179)

*Dinitrobenzocarbazole*, $C_{16}H_9N_3O_4$. One isomer is described in Beil **20**,(179)

*Trinitrobenzocarbazole*, $C_{16}H_8N_4O_6$, not found in Beil or CA thru 1956

*Tetranitrobenzocarbazole*, $C_{16}H_7N_5O_8$, not found in Beil or CA thru 1956

**Pentanitrobenzocarbazole**, $C_{16}H_6N_6O_{10}$; mw 442.18, N 19.01%. One isomer, *x,x,x,x,x-Pentanitro-2,3-benzocarbazole* is described in the literature. The compd is in the form of golden-yel lfts, mp 256°; nearly insol in most org solvents. Was prepd by heating 2,3-benzocarbazole or x,x -dinitro-2,3-benzocarbazole with mixed nitric -sulfuric acid. Its expl props were not investigated

*Refs*: 1)Beil **20**,(179) 2)F.Kehrmann et al,Ber **46**,3716(1913)

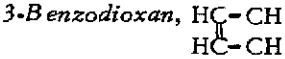
*Note*: No later Refs on pentanitrobenzocarbazole were found in CA thru 1960

**Benzodiazoles.** See under Aminoindazoles, Vol 1,p A224-L

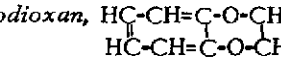
**Benzodioxadiazine.** See Benzofuroxan

**Benzodioxan and Derivatives**

*Benzodioxan* (Ethylenedioxybenzene or Pyrocatechol Ethylene Ether), $C_8H_8O_2$; mw 136.14, O 23.50%. This compd exists in two configurations: *1,3-Benzodioxan*,



and *1,4-Benzodioxan*,



. Both forms are aromatic oily liquids. Their props & prepn are given in Beil **19**,22,(613) & [20,21]

*Mononitrobenzodioxan*, $C_8H_7NO_4$; mw 181.14, N 7.73%. The *6(or 7)-Nitro deriv* of 1,4-benzodioxan (called 4-Nitro deriv by Vorländer and by Heertjes et al); ndls(from w or alc), mp 121-2°, was prepd

by direct nitration of the parent compd(Refs 1,2, 3 & 4)

*Refs*: 1)Beil **19**,22 2)D.Vorländer,Ann **280**,206 (1894) 3)P.M.Heertjes et al, Rec **60**,572(1941) & CA **37**,620(1943) 4)P.M.Heertjes & L.J.Revallier, Rec **69**,263(1950)

**Dinitrobenzodioxan**, $C_8H_6N_2O_6$; mw 226.14, N 12.39%. The *6,7-Dinitro deriv* (called 4,5-dinitro -1,2-ethylene-dioxybenzene by Ghosh,Robinson & Robinson and by Heertjes et al), lt yel ndls(from glac AcOH+alc), mp 131-2°, was prepd by nitration of the 7-nitro deriv using a nitric-sulfuric acid mixt of very definite concn, at 90-95°(Ref 4). Its expl props were not detd(Refs 1,2,3 & 4). There were prepd later by Heertjes et al(Refs 5 & 6), the *5,7-Dinitro deriv*, lt yel ndls(from acet), mp 145.5-145.7°, indirectly via 3,5-dinitropyrocatechol, because no direct method of nitrating the parent compd had been found(Ref 5), and the *5,6-Dinitro deriv*, yel ndls(from alc), mp 185.6 -186.1°, obtd by dinitration, either directly or via the mononitro deriv of 6-acetamidobenzo-1,4-dioxan, followed by deacetylation and deamination (Ref 6). The *5,8-Dinitrobenzo-1,4-dioxane*, yel crysts(from ligroin or aq alc), mp 99.6-102.5°, was prepd by condensation of 3,6-dinitropyrocatechol with ethylene bromide(Ref 6). These compds were prepd as possible substituents for azo dyes and their expl props were not detd

*Refs*: 1)Beil **19**,(613) 2)B.N.Ghosh,JCS **107**, 1591(1915) 3)G.M.Robinson & R.Robinson,JCS **111**,935(1917) 4)P.M.Heertjes et al,Rec **60**, 572-3(1941) & CA **37**,620(1943) 5)P.M.Heertjes et al,JCS **1954**,1869 & CA **49**,9655(1955) 6)P.M. Heertjes et al,JCS **1955**,1316 & CA **50**,2600(1956)

**Trinitrobenzodioxan**, $C_8H_5N_3O_8$, mw 271.14, N 15.50%. The *5,6,7(or 6,7,8)-deriv* called 4,5,6(or 3,4,5)-trinitro-1,2-ethylenedioxybenzene by Heertjes et al, lfts or ndls (from alc), mp 156°, can be prepd by nitration of the 6,7-dinitro compd (Refs 1,2 & 3) or more conveniently by nitration of the 6(or 7)-mononitro deriv(Ref 4). The *5,6,8 -Trinitro-1,4-dioxan*, yel ndls(from alc and from isobutanol), mp 180.4-181.0°, was prepd by nitration of the 5,6-dinitro deriv(Ref 5). Their expl props were not detd

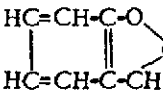
*Refs*: 1)Beil **19**,(614) 2)B.N.Ghosh,JCS **107**, 1592(1915) 3)G.M.Robinson & R.Robinson,JCS **111**,935(1917) 4)P.M.Heertjes et al,Rec **60**,574 (1941) & CA **37**,620(1943) 5)P.M.Heertjes et al, JCS **1955**,1315 & CA **50**,2600(1956)

**5,6,7,8-Tetranitrobenzo-1,4-dioxan** (called 3,4,5,6 -Tetranitro-1,2-ethylenedioxybenzene by Heertjes et al), $C_8H_4N_4O_{10}$, mw 316.14, N 17.72%; wh crysts(from alc), mp 286°, expl at higher temp. Was prepd by nitration at 70° of a soln of the 5,6,7-trinitro deriv in sulfuric acid. Expln of this compd could not be prevented during detn of its N content

*Refs*: 1)Beil- not found 2)P.M.Heertjes et al, Rec **60**,575(1941) & CA **37**,620(1943)

### Benzofuran and Derivatives

*2,3-Benzofuran or Coumarone* (Cumaron in Ger),



; col aromatic-smelling oil; fr p below -18°, bp 173-4°, d 1.078 at 15/15°, $n_D$ 1.56897 at 16.3°. Other props & prepn are given in the Refs. Has been used in resins(such as coumarone-indene resin), plastics, paints and varnishes

*Refs*: 1)Beil **17**, 54,(24) & [57] 2)Thorpe **3** (1939),411 3)Kirk & Othmer **4**(1949),594-600

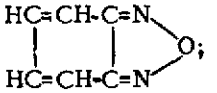
**Mononitrobenzofuran**, $C_8H_5NO_3$; mw 163.13, N 8.59%. The following isomers are described in the literature: *2-Nitro-*, col ndls, mp 134°(Ref 1); *x-Nitro-*, yel ndls, mp 85°(Ref 1); *5-Nitro-*, col lfts, mp 114-115°(Ref 2) and *6-Nitro-*, yel pdr, mp 246-7° with decompn(Ref 3)

*Refs*: 1)Beil **17**,59 2)H.Erlenmeyer et al,Helv **31**,77(1948) & CA **42**,4167(1948) 3)P.Rumpf & C.Gansser,Helv **37**,435-6(1954) & CA **49**,6216 (1955)

*Dinitro-*, $C_8H_4N_2O_5$ *and Trinitro-*, $C_8H_3N_3O_7$ Benzofurans were not found in Beil or in CA thru 1956

### Benzofurazan and Derivatives

*Benzofurazan or 2,1,3-Benzoxadiazole* (called 3.4-Benzo-1.2.5-oxdiazol or Benzfurazan in Ger) formerly called Benzochinon-(1.2)-dioxim or o -Chinondioxim in Ger(Ref 1a),



; mw 120.11, N 23.33%; peculiar-smelling ndls(from dil alc), mp 55°, readily volatile in steam; sol in most org solvs. Other props & prepn are given in Refs

*Refs*: 1)Beil **27**,568 & (573) 1a)Beil **7**,601 & (338) 2)T.Zincke & P.Schwarz,Ann **307**,40(1899) 3)A.Hantzsch & W.H.Glover,Ber **39**,4170(1906) & **40**,4346(1907) 4)A.G.Green & F.M.Rowe,JCS **101**,2456(1912) & **111**,618(1917) 5)R.J.Gaughran

et al,JACS **76**,2234(1954) & CA **49**,6238(1955)
*Mononitrobenzofurazan*, $C_6H_3N_3O_3$, mw 165.11, N 25.45%. The *4-Nitro deriv*, lt yel crysts(from nitric acid), mp 98°; insol in w; sol in most org solvents. Was prepd by treating benzofurazan with concd nitric-sulfuric acid. This compd is called "Furazano della 1-nitro-o-chinondiossima" in Ref 3
*Refs*: 1)Beil **27**,659 2)P.Drost,Ann **307**,69(1899) 3)M.Milone & G.Tappi,AttiAccadSciTorino **75** I, 458-9(1940) & CA **37**,1309(1943)
*Note:* No higher nitrated derivs of benzofurazan were found in Beil or in CA thru 1956

**Benzofurezen Oxide**, Same as Benzofuroxan

**Benzofuroxan and Derivatives**

*Benzofuroxan; Benzofurazan Oxide; Benzodioxadiazine* or *Quinonedioxime Peroxide* (formerly called "o-Dinitrosobenzene", which is incorrect) (called 3,4-Benzo-1,2,5-oxdiazol-2,5-oxyd or Benzfurazan-1,3-oxyd in Ger), HC=CH-C=N-O; HC=CH-C=N-O; HC=CH-C=N-O HC=CH-C=N-O or HC=CH-C=N→O HC=CH-C=N→O (despite 60 years of research to elucidate its structure, available evidence is insufficient to permit a choice among the various structures suggested, hence, none can be eliminated); mw 136.11, N 20.58%; wh ndls(from alc or w) or almost col lfts (from benz), mp 72°. Other props & prepn are given in Refs 1,2,3 & 4
*Refs*: 1)Beil **7**,601 and **27**,(622) & [629] 2)E. Noelting & A.Kohn,ChemZtg **18**,1905(1894) 3)R. J.Gaughran et al,JCS **76**,2223(1954) 4)J.V.R. Kaufman & J.P.Picard,ChemRevs **59**,429-61(1959)
**6-Azido-5-nitrobenzofuroxan**, $C_6H_2N_6O_4$; mw 222.12, N 37.84%; dk yel ndls(from alc), mp 89° (dec), expl violently when heated rapidly above its mp. Was prepd by heating 1,3-dinitro-4,6-diazidobenzene at 80-85° until the evolution of N ceased. Further nitration converted this compd, on standing, to *nitrobenzodifuroxan*, $C_6H_2N_5O_6$
*Refs*: 1)Beil- not found 2)J.R.Gaughran et al, JACS **76**,2235(1954) & CA **49**,6238(1955)
**Mononitrobenzofuroxan**, $C_6H_3N_3O_4$; mw 181.11, N 23.20%. The *4-Nitro*, yel lfts(from glac AcOH), mp 143°(Refs 1,2,3,4a,4 & 5) and the *5-Nitro deriv*, yel lfts(from dil alc or benz), mp 72°, expl (Refs 1,2,4 & 5) are described in the literature
*Refs*: 1)Beil **7**,608 & **27**,(623) & [629] 2)P. Drost,Ann **307**,54 & 65(1899) 3)A.G.Green & F.M.Rowe,JCS **103**,2028(1913) 3a)M.Milone & G.Tappi,AttiAccadSciTorino **75** I,459(1940) 4)R.J.Gaughran et al,JACS **76**,2235(1954) 5)J.V. R.Kaufman & J.P.Picard,ChemRevs **59**,448(1959)
**Dinitrobenzofuroxan**, $C_6H_2N_4O_6$; mw 226.11, N 24.78%. Three isomers are described in the literature:
*4,6-Dinitrobenzofuroxan* (formerly called "4,5-Dinitro-1,3-dinitrosobenzene"), yel ndls(from glac AcOH), mp 172°; sol in most org solvs. Can be prepd either by heating 2,4,6-trinitrophenylazide at 90-100° or by nitrating benzofuroxan with a sulfuric-nitric acid mixt at 5-20°(Refs 1,2,3 & 9) or by other methods(Refs 4,8 & 11). This compd is an expl, ca 130% as powerful as PA, but is too sensitive for use as a HE. It is stable in storage at 80° (Ref 7). Some of its salts are more stable and less impact-sensitive expls and, therefore, may find use in primary expl compns.
The *Potassium salt*, (KDNBF), $\left[O_2N.C=CH-C=N\begin{smallmatrix}\diagup O\\ \diagdown O\end{smallmatrix} \atop HC=C-C=N\begin{smallmatrix}\diagup O\\ \diagdown O\end{smallmatrix} \atop NO_2\right]K$; mw 264.20, N 21.21%, OB to $CO_2$,$H_2O$ & $K_2O$ -42.4%, red crysts, golden yel lfts(from w)(Refs 9 & 10). The following props, apparently for the anhydrous salt, are given in Ref 10: mp expl at 210°, d 2.21; friction sensitivity- expl with fibre or steel shoe; gas volume developed on expln 604cc/g; hygroscopicity at 30° & 90%RH- gain 0.27%; impact sensitivity, PicArsnApp, 1-lb wt 6"; initiation sensitivity- requires 0.30g MF or 0.10g LA; sand test- 44.8g sand crushed vs 48.0g for TNT; solubility 0.245g per 100g water at 30°; specific heat 0.217cal/g/°C for temps betw -50 and +50°; staby test(see Ref 10,p 263); volatility at 100°(heat test) % loss 1st 48hrs 0.03%, 2nd 48hrs 0.05, no expln in 100hrs. According to Refs 5 & 6, its sensitivity value is betw MF & LA(See also Ref 9a)
*Silver salt*, $AgC_6HN_4O_6$, red crysts, mp expl on heating(Ref 2); and *Sodium salt*, $NaC_6HN_4O_6$, red crysts, mp expl on heating(Ref 2)
*5,6-Dinitrobenzofuroxan* (formerly called "4,5-Dinitro-1,2-dinitrosobenzene"), lt yel cryst(from nitric acid), mp 172°(dec); sol in benz, diffc sol in alc; was obtd by Drost(Ref 2) on nitrating the 5-mononitrobenzofuroxan with nitric acid and pptg the resulting product with w. This compd forms addn products with aniline or naphthalene (Ref 1)(See also Ref 6b)
*4,7-Dinitrobenzofuroxan*, yel to brn crysts(from acet), mp ca 182°; sol in hot w, MeOH, acet or benz; sl sol in chlf or ligroin; insol in $CCl_4$. Two methods for its prepn are described by Borsche &

Weber(Ref 6a)
*Refs*: 1)Beil **7**,608-9 and **27**,(623) & [629-30] 2)P.Drost,Ann **307**,55 & 57(1899) 3)A.G.Green & F.M.Rowe,JCS **103**,2029(1913) 4)E.Schrader,Ber **50**,778(1917) 5)L.Metz,SS **23**,305-8(1928) 6)H. Rathsburg,AngChem **41**,1284(1928) 6a)W.Borsche & H.Weber,Ann **489**,291(1931) & CA **26**,708(1932) 6b)M.Milone & G.Tappi,AttiAccadSciTorino **75** I, 460(1940) 7)Blatt,OSRD **2014**(1944) 8)J.Gillis & J.Hoste,AnalChimActa **1**,326-9(1947) & CA **42**, 4485(1948) 9)R.J.Gaughran et al,JACS **76**,2234 (1954) & CA **49**,6238(1955) 9a)M.Baer,"Pilot Plant Preparation of KDNBF", PATR **2122**(1955)(Conf) 10)PATR **1740**,Rev 1(1958),261-4 11)J.V.R.Kaufman & J.P.Picard,ChemRevs **59**,448(1959)
*Note*: Compare with info on Dinitrodinitrosobenzene under Benzene and Derivatives

### Benzohydroxamic Acid and Derivatives

**Benzohydroxamic Acid**(called Benzhydroxamsäure, N-Benzoylhydroxlamin or Benzyhydroximsäure in Ger), $C_6H_5.CO.NH.OH$ or $C_6H_5.C(OH):N.OH$; mw 137.13, N 10.21%; rhom lfts(exists in two isometric types), mp 124-6° & 131-2° (values reported by various investigators); expl or rapid heating; v sol in alc; sl sol in w or eth; insol in benz. Can be prepd by the action of hydroxylamine on the esters, chloride or amide of benzoic acid and by other methods(Ref 1). It forms numerous addn compds and salts, such as the *Copper salt*, $Cu(C_7H_6NO_2)_2$, lt blue cryst which expl mildly on heating(Ref 2)
*Refs*: 1)Beil **9**,301,(128) & [213] 2)L.Balbiano, AttiAccadLinceiRend [5] **21** I,392 (1912)
**Mononitrobenzohydroxamic Acid**, $O_2N.C_6H_4.CO.NH.OH$, mw 182.13, N 15.38%. Two isomers are described in the literature:
*3-Nitrobenzohydroxamic Acid*, granules(from chlf), mp 153° (dec). Its *Sodium salt*, $NaC_7H_5N_2O_4$, yel cryst, expl on heating(Refs 1 & 3) *4-Nitrobenzohydroxamic Acid*, lfts(from boiling w) or monoclinic prisms, mp 238-40°, forms numerous metallic salts, some of which undoubtedly are expl(Ref 2)
*Refs*: 1)Beil **9**,387 & [255] 2)Beil **9**,389-90 3)J.Meisenheimer & E.Patzig,Ber **39**,2542(1906)
*Note*: *Dinitro*-$C_7H_5N_3O_6$ and *Trinitro*-$C_7H_4N_4O_8$ *Derivs* were not found in Beil or in CA thru 1956

**Benzohydroxytriazine.** See under Benzotriazine

**Benzohydroxytriazole.** See under Benzotriazole

**Benzohydryl Azidodithiocarbonate.** See Vol 1,p A633-L

### Benzoic Acid and Derivatives

**Benzoic Acid**, *Benzenecarboxylic Acid or Phenylformic Acid*(called Benzoesäure or Benzolcarbonsäure in Ger), $C_6H_5.COOH$; mw 122.12, O 26.20%, OB to $CO_2$ -196.5%, monocl prisms, mp 121°;(sublimes at 100°), fl p 121°, d 1.316, vap press 1mm at 96.0°; sol in alc 46.6% at 15°, in acet 55.6% at 25°, in eth 40.8% at 25°, in w 0.21% at 17.5° & 2.2% at 75°. According to Hackh's(Ref 3) benzoic acid is poisonous to man but Sax(Ref 7) considers its toxicity by ingestion, inhalation or exposure as slight. Can be prepd by the decarboxylation of phthalic acid dissolved in phthalic anhydride, or by the catalytic oxidn of toluene(Refs 1,2,4,5 & 6). Benzoic acid occurs in benzoin and in cranberries. This compd forms numerous salts and addn compds(Ref 1a)

It is used as an antipyretic, antiseptic or expectorant; used in calico printing and in the manuf of aniline dyes(Ref 3). In the pure state it is used as a std in acidimetry, thermometry and calorimetry. Its nitro compds have been used in the expl industry
*Refs*: 1)Beil **9**,92,(54) & [72] 1a)Beil **9**,107,(59) & [83] 2)Thorpe **1**(1937),678-82 3)Hackh's(1944), 114 4)Kirk & Othmer **2**(1948),459-77 5)OrgSynth-CollVol **3**(1955),334 & 337 6)Faith,Keyes & Clark (1957),151-6 7)Sax(1957),349

**Azido- and Azides of Benzoic Acid and Derivatives**

**Azidobenzoic Acid**(called Azido- or Triazo-benzoesäure in Ger), $N_3.C_6H_4CO_2H$; mw 163.12, N 25.76%. The *2-Azido*, ndls(from w), mp 146°(dec); *3-Azido*, lfts, mp 159-160° and the *4-Azido deriv*, lfts, mp 145°(dec)(Ref 2) are described in the literature(Ref 1)
*Refs:* 1)Beil **9**,418,(168-9) & [286] 2)S.Maffei & L.Coda,Gazz **85**,1300(1955) & CA **50**,9330(1956)
**3,5-Diazidobenzoic Acid**, $(N_3)_2C_6H_3.CO_2H$, mw 204.15, N 41.17%; ndls(from dil alc), mp expl violently on heating; v sol in eth, readily sol in hot alc; nearly insol in w. Can be prepd by treating an ammoniacal soln of 5-azido-1-carboxybenzene-3-diazoniumperbromide with HCl
*Refs*: 1)Beil **9**,419 2)P.Griess,Ber **21**,1564(1888)
*Note*: A number of azidophenylesters and their nitrated derivs of benzoic acid have been described in the literature: Beil **9**,119,379 & 391 and (169)
**Benzoyl Azide or Benzazide(Benzoylazoimide)** (called Benzoesäureazid; Benzoylazid or Benz-

azid in Ger), $C_6H_5.CO.N_3$; mw 147.13, N 28.56%; col plates(from acet), mp 32°, expl on further heating; sol in eth, sl sol in alc insol in w. Curtius (Ref 2) observed the compd had a pungent odor, was poisonous and attacked the skin, while Werle & Friend(Ref 6) reported an effect of lowering the blood press and producing 10 times as much biological action as Na azide. Can be prepd by adding Na nitrite and AcOH to an ice-cold aq soln of benzhydrazide. Other methods of prepn and props are given in Refs 1,2,3 & 4

Benzoyl azide is extremely sensitive to impact or friction, exploding even when pressed with a glass rod. The crude prod expl at ca 150° and its sensitivity is increased by small amounts of impurities or by confinement. Bergel(Ref 3) described two explns which took place during its prepn by the Gattermann-Wieland method from ethylbenzoate

The Raman spectra(Ref 5) and dipole moment (Ref 7) of benzoyl azide have been detd

*Refs*: 1)Beil **9**,332 & [219] 2)T.Curtius,Ber **23**, 3029(1890) & JCS **60** I,56(1891);JPraktChem **50**, 286(1894) & JCS **68** I,33(1895) 3)F.Bergel,AngChem **40**,974(1927) & CA **21**,3463(1927) 4)V.V. Vasilevskii et al,ZhObshchKhim **5**,1652(1935) & CA **30**,3416(1936) 5)Yu.N.Sheinker & Ya.K. Syrkin,IzvestAkadN,SerFiz **14**,478(1950) & CA **45**, 3246(1951) 6)E.Werle & R.Friend,BiochemZ **322**, 506(1952) & CA **46**, 10440(1952) 7)E.A.Shott -L'vova & Ya.K.Syrkin,DoklAkadN **87**,639(1952) & CA **47**,6203(1953)

**Mononitrobenzoyl Azide**, $O_2N.C_6H_4.CO.N_3$; mw 192.13, N 29.16%. Three isomers are described in the literature:

*2(or o)-Nitrobenzoyl Azide*, yel prisms(from eth), mp 36-9°(dec); readily sol in eth, chlf or benz; diffc sol in petr eth. Can be prepd from 2-nitrobenzoylhydrazine in dil $HNO_3$ soln and aq $NaNO_2$ or with benzenediazonium sulfate and by other methods(Refs 1,2,3,4 & 5). This compd can be used as a reagent for the identification of phenols (Refs 5 & 6)

*Refs*: 1)Beil **9**,376 2)A.Struve & R.Radenhauser, JPraktChem **52**,231(1895) & JCS **70** I,35(1896) 3)V.V.Vasilevskii et al,ZhObshchKhim **5**,1652 (1935) & CA **30**,3416(1936) 4)C.Naegeli et al, Helv **21**,1137(1938) & CA **33**,540(1939) 5)P.P. T.Sah & Wen-Hou Yin,Rec **59**,238(1940) & CA **34**, 5786(1940) 6)P.P.T.Sah et al,JChineseChemSoc **13**,22(1946) & CA **42**148(1948)

*3(or m)-Nitrobenzoyl Azide*, wh lfts(from alc), mp 68°, expl on further heating; easily sol in eth, benz, alc or AcOH; insol in w. Can be prepd by diazotization of 3-nitrobenzoylhydrazine or its reaction with benzenediazonium sulfate(Refs 1 & 2) and by other methods(Refs 3,5,6 & 8). This compd can be used as an identifying reagent for amines(Refs 4,5 & 7) and phenols(Refs 5 & 6)

*Refs*: 1)Beil **9**,388 2)A.Struve & R.Radenhausen, JPraktChem **52**,228(1895) & JCS **70** I,35(1896) 3)V.V.Vasilevskii et al,ZhObshchKhim **5**,1652 (1935) & CA **30**,3416(1936) 4)Kwang-Chun Meng & P.P.T.Sah,JChineseChemSoc **4**,75(1936) & CA **30**,8181(1936) 5)S.Veibel & H.Lillelund,Dansk-TidsFarm **14**,236(1940) & CA **35**,2441(1941); **17**, 183(1943); ChemZtr **1944** I,173 & CA **39**,1608 (1945) 6)P.P.T.Sah et al,JChineseChemSoc **13**, 22(1946) & CA **42**,148(1948) 7)K.J.Karrman, SvenskKemTid **60**,61(1948) & CA **42**,5804(1948) 8)J.Munch-Peterson,ActaChemScand **5**,1408(1951) & CA **46**,8634-5(1952) and OrgSynth **33**,53(1953) & CA **49**,7521(1955)

*4(or p)-Nitrobenzoyl Azide*, col lfts(from alc+w), mp 71-2°; soly similar to the meta deriv; can be prepd by procedures similar to those used for ortho and meta derivs(Refs 1,2 & 5) and by the reaction of p-nitrobenzoylchloride and Na azide soln(Ref 4). This compd can be used as a reagent for identification of amines(Ref 3) and phenols (Ref 3)

*Refs*: 1)Beil **9**,400 2)A.Struve & R.Radenhausen,JPraktChem **52**,232(1895) & JCS **70** I, 35(1896) 3)P.P.T.Sah et al,Rec **58**,595 & 1013 (1939) & CA **33**,6746(1939) & **34**,1583(1940) and Rec **59**,231(1940) & CA **34**,5786(1940) 4)J.Munch -Peterson,ActaChemScand **5**,1408(1951) & CA **46**, 8634-5(1952); OrgSynth **33**,53-5(1953) 5)K.Hutton, JOC **20**,858(1955) & CA **50**,5674(1956)

**Dinitrobenzoyl Azide**, $(O_2N)_2C_6H_3.CO.N_3$; mw 237.13, N 29.54%. Two isomers are described in the literature:

*4,6-Dinitrobenzoyl Azide*,(2,4-Dinitrobenzoyl Azide), lt yel cryst, mp 68°(dec); sol in common org solvs but insol in aliphatic hydrocarbons; was prepd from 4,6-dinitrobenzoylchloride and aq Na azide. Its expl props were not investigated (Ref 2)

*Refs*: 1)Beil- not found 2)C.Naegeli et al,Helv **21**,1138(1938) & CA **33**,540(1939)

*3,5-Dinitrobenzoyl Azide*, wh cryst ppt, mp 107°, expl on further heating; sol in alc or eth; insol

in w; was prepd from 3,5-dinitrobenzoyl hydrazide and Na nitrite in AcOH soln(Refs 1 & 2) or by other methods(Refs 3,5,6 & 7). This compd can be used for the identification of phenols because it forms dinitrophenylurethanes having definite mp's(Ref 4)

*Refs*: 1)Beil **9**,415 2)T.Curtius & A.Riedel, JPraktChem **76**,246(1907) & JCS **92** I,970(1907) 3)J.J.Blanksma & G.Verberg,Rec **53**,989(1934) & CA **29**,462(1935) 4)P.P.T.Sah & Tsu-Sheng Ma,JChineseChemSoc **2**,159(1934) & CA **29**,465 (1935) 5)H.Degiorgi & E.V.Zappi,BullFr[5]**4**, 1636(1937) & CA **32**,518-9(1939) 6)L.I.Smith & J.A.Sprung,JACS **64**,433(1942) & CA **36**1932(1942) 7)A.A.Bothner-By & L.Friedman,JACS **73**,5391-2 (1951) & CA **47**,515(1953)

**2,4,6-Trinitrobenzoyl Azide,** $(O_2N)_3C_6H_2.CO.N_3$; mw 282.13, N 29.79%; col cryst(from methyl acet), mp 92-6°(dec)(Ref 2) to 98°(dec)(Ref 3), expl at higher temps; d 1.673 at 20°(Ref 2); sol in acet or aromatic hydrocarbons; insol in aliphatic hydrocarbons(Ref 3); can be prepd by adding aq Na azide soln in methyl acet to a stirred soln of 2,4,6-trinitrobenzoyl chloride in methyl acet at -5 to 0° (higher temps must be avoided)(Ref 2). This compd decomposes at RT and especially rapidly in soln

Vasilevskii et al(Ref 2) studied the expl props of this compd from the viewpoint of its structure and from measurements of N evolution at 20° & 35° and found the trinitro deriv and benzoyl azide to have the same order of stability. However, both compds were less stable than the ortho-nitro and meta-nitro derivs; the meta- or 3-nitrobenzoyl azide was the most stable deriv

*Refs*: 1)Beil- not found 2)V.V.Vasilevskii et al, ZhObshchKhim **5**,1652(1935) & CA **30**,3416(1936) 3)C.Naegeli et al,Helv **21**,1138-9(1938) & CA **33**, 540(1939)

**Benzoyl Azide-Benzalhydrazone,** or Benzoyl Azide-Benzylidenehydrazone $C_6H_5.CO(N_3):N-.N:CH.C_6H_5$; mw 265.27, N 26.40%; yel ndls (from eth or alc), mp 72°, expl on heating rapidly above mp; sol in alc or eth; insol in w;was prepd by the action of an aq soln of Na nitrite and dil HCl on an alc-eth suspension of benzal-benzohydrazidine (or α-hydrazino-dibenzylidinehydrazine), $H_2N.NH.C(C_6H_5):N.N:CH.C_6H_5$. On heating benzoylazide -benzalhydrazone in alc soln, there was formed *1-Benzalamino-5-phenyl 1,2,3,4-tetrazole* or [*1-Benzylidineamino-5-phenyl-α(or 1H)-tetrazole*], $H_5C_6.\underset{\underset{N}{\|}}{C}-N(N:CH.C_6H_5)-\underset{\underset{N}{\|}}{N}$; col ndls, mp 105°, which expl mildly on heating above mp

*Refs*: 1)Beil **9**,(136) 2)R.Stollé & F.Helwerth, Ber **47**,1139(1914) & JCS **106** I,750(1914)

**Nitro and Other Derivatives of Benzoic Acid**

**Mononitrobenzoic Acid**(MNBAc), $O_2N.C_6H_4.CO-OH$; mw 167.12, N 8.38%, OB to $CO_2$ -119.7%. Three isomers are described in the literature: *2-Nitrobenzoic Acid*, col ndls(from w), mp 144 -8°; $Q_C^P$ 730-735kcal/mol(Refs 1 & 6) *3-Nitrobenzoic Acid*, monoclinic yel prisms, mp 140-1°; $Q_C^P$ 729kcal/mol(Refs 2 & 5) Nishi & Toki(Ref 4) investigated a number of methods of its prepn from benzaldehyde and noted that reaction with nitric -sulfuric acid mixts above 100° led to explosions *4-Nitrobenzoic Acid*, lfts(from boiling w), mp 238 -40°; $Q_C^P$ 728kcal/mol(Ref 3)

*Refs*: 1)Beil **9**,370,(150) & [242] 2)Beil **9**,376, (153) & [247] 3)Beil **9**,389,(157) & [256] 4)T. Nishi & H.Toki,JSocChemInd(Japan) **45**,Suppl-Binding 37-8(1942) & CA **44**,11099(1950) 5)Y. Hirata & T.Goto,ResRept,NagoyaIndSciResInst No **6**,37(1953) & CA **49**,2363(1955) 6)T.Kosuge & S.Miyashita,PharmBull(Japan) **2**,397(1954) & CA **50**,12057(1956)

**Nitrosonitrobenzoic Acid,** $O_2N.C_6H_3(NO).CO_2H$; mw 196.12, N 14.29%. The *2-Nitroso-4-nitro deriv* lt grn-yel lfts(from et acet), mp above 300°(Refs 1,3 & 4) the *4-Nitroso-2-nitro deriv*, yel cryst(from glac AcOH), mp darken at 210° and ca 230°(dec) on rapid heating(Refs 2 & 4) and the *4-Nitroso-3 -nitro deriv*,mp 170°(dec)(Ref 5) are described in the literature

*Refs*: 1)Beil **9**,411 & [279] 2)Beil **9**,[278] 3)P. Friedländer & P.Cohn,Ber **35**,1267(1902); Montash **23**,561(1902) & JCS **82** I,792(1902) 4)G.Heller, JPraktChem **106**,12(1923) & CA **17**,3867(1923) 5)E.Borel & H.Deuel,Helv **36**,806(1953) & CA **47**, 9220(1953)

**Dinitrobenzoic Acid** (DNBAc), $(O_2N)_2C_6H_3.CO_2H$; mw 212.12, N 13.21%. The following six isomers are described in the literature: *2,3-Dinitro-*, small crysts, mp 201°(Refs 1 & 18); *2,4-Dinitro-*, ndls, tablets or prisms, mp 180-3°(Refs 2,16,17 & 19) *2,5-Dinitro-*, monocl prisms, mp 177-9°(Ref 3 & 18) *2,6-Dinitro-*, ndls, mp 201-3°(Refs 4 & 18) *3,4-Dinitro-*, ndls, monocl prisms, mp 161-5°(Ref 5) and *3,5-Dinitro-*, monocl prisms, mp 202-5° (Refs 6,8 & 15). For prepn and other props, see

the Refs indicated

All of these isomers form nitrophenyl esters and numerous salts, the following of which are the more important expls:

*Barium Salt of 3,5-Dinitrobenzoic Acid*(Barium-3,5-dinitrobenzoate), $Ba(C_7H_3N_2O_6)_2+5H_2O$; lt yel ndls, mp 201-6°, expl mildly above the mp(Refs 6 & 6a)

*Normal Lead Salt of 2,4-Dinitrobenzoic Acid(N-Lead-2,4-dinitrobenzoate)*, $[(O_2N)_2C_6H_3COO]_2Pb$; fine ndls; was prepd by Schaefer(Ref 12) from a soln of Pb acetate and an alc soln of 2,4-dinitrobenzoic acid. Its expl props were not investigated, but Schmitt(Ref 11a) found it stable at 300°

*Normal Lead Salt of 3,5-Dinitrobenzoic Acid(N-Lead-3,5-dinitrobenzoate)*, brn amor pdr, mp 300-5°(dec); can be prepd by treating 3,5-dinitrobenzoic acid with Pb acetate in alc soln(Ref 13) or with Pb nitrate and NaOH solns(Ref 14). This salt is an expl about 34% as powerful as TNT(by BalMort test) and of about the same sensitivity as TNT; its thermal stability is satisfactory and hygroscopicity at 90% RH is negligible(Ref 13). Brün(Ref 9) and later Burdett & Calhoun(Ref 14) recommended the use of this salt as an ingredient of priming compns, such as Pb-dinitrobenzoate 8, LSt 40, tetracene 2, Pb nitrate 30 & glass 20%

*Basic Lead Salt of 2,4-Dinitrobenzoic Acid(β-Lead-2,4-dinitrobenzoate)*, $(O_2N)_2C_6H_3.COOPb(OH)$; crysts, mp expl on rapid heating to high temp; was prepd as mono and dibasic Pb salts by treating 2,4-dinitrobenzoic acid with a Pb compd. Brün(Ref 11) proposed the use of basic lead dinitrobenzoate as an ingredient of priming compns, together with MF, Ba nitrate and an abrasive

*Basic Lead Salt of 3,5-Dinitrobenzoic Acid(β-Lead-3,5-dinitrobenzoate)*, crysts, mp expl on heating to high temp; was prepd by the action of Pb nitrate and NaOH on the dinitrobenzoic acid in aq soln. Patented by Friederich(Ref 7) and by Brün (Ref 10) as an ingredient of priming compns

*Silver Salt of 3,5-Dinitrobenzoic Acid* (Silver-3,5-dinitrobenzoate), $AgC_7H_3N_2O_6$; yel ndls(from w), mp expl violently on heating(Refs 6 & 6a)

*Refs*: 1)Beil **9**,411 & [279] 2)Beil **9**,411(166) & [279] 3)Beil **9**,412 & [279] 4)Beil **9**,412,(166) & [279] 5)Beil **9**,413,(167) 6)Beil **9**,413,(167) & [279] 6a)D.Muretow,ChemZtr **42**,19(1918) 7)W. Friederich,BritP 192830(1921) & JSCI **42**,332A (1923) 8)P.P.T.Sah et al, SciRptsNatlTsinghuia Univ **A2**,137(1933) & CA **28**,118(1934) 9)W.Brün, USP 1887919(1932) & CA **27**,1513(1933) 10)W. Brün,USP 1971029(1934) & CA **28**,6314(1934) 11)W.Brün,USP 1991730(1935) & CA **29**, 2360 (1935) 11a)R.Schmitt,MP **27**,150(1937) & CA **31**, 8199(1937) 12)M.Schaefer,MP **27**,153(1937) & CA **31**,7864(1937) 13)R.McGill,OSRD **830**(1942),p33 14)P.H.Burdett & G.M.Calhoun,USP 2345868(1944) & CA **38**,4806(1944) 15)F.Weygand & H.Hofmann, ChemBer **83**,405(1950) & CA **44**,10051-2(1950) 16)G.Machek,ÖsterrChemZtg **54**,182(1953) & CA **49**,2363(1955) 17)J.P.Blanchard & H.L.Goering, JCS **1954**,2977 & CA **49**,10880(1955) 18)T. Kosuge & S.Miyashita,PharmBull(Japan)**2**,397 (1954) & CA **50**,12057(1956) 19)C.Martinuzzi & A.Vecchi,Gazz **82**,671-3(1954) & CA **48**,9344 (1954)

**2,4-Dinitrobenzoic Acid; 6,6-Azoxy- or 2,2'-Azoxy-4,6-dinitrobenzoic Acid.** See below under 6-Nitroso-2,4-Dinitrobenzoic Acid

**Dinitrobenzoic Acid Hydrazide or Dinitrobenzoylhydrazide,** $(O_2N)_2C_6H_3.CO.NH.NH_2$; mw 226.15, N 24.78%. Two isomers are described in the literature: *2,4-Dinitrobenzoic Acid Hydrazide* (2,4-Dinitrobenzoic Acid Hydrazide), orn-yel cryst (from abs alc), mp 231-3°; was prepd in small quant by treating the methyl or ethyl ester of 2,4-dinitrobenzoic acid with hydrazine sulfate(Ref 3)

*3,5-Dinitrobenzoic Acid Hydrazide*(called 3.5-Dinitro-benzoylhydrazid in Ger), yel ndls(from alc), mp 158°; was prepd by heating the ethyl ester of 3,5-dinitrobenzoic acid with hydrazine hydrate in abs alc. The *Sodium salt*, $NaC_7H_5N_4O_5$, brn cryst, decrepitates on heating(Refs 1 & 2)

*Refs*: 1)Beil **9**,414 2)T.Curtius & A.Riedel,J-PraktChem 76.243(1907) 3)G.Carrara et al,Gazz **82**,652 (1952) & CA **48**,6424(1954)

**6-Nitroso-2,4-Dinitrobenzoic Acid or 2-Nitroso-4,6-Dinitrobenzoic Acid,** $(O_2N)_2C_6H_2(NO).CO_2H$; mw 241.12, N 17.43%; grn ndls, mp 200.5°; easily sol in w, alc, acet, et acet or hot benz; insol in $CCl_4$. Was obtd by Joshi & Patwardhan(Ref 4) after 2 hrs exposure to sunlight of a satd soln of 2,4,6-trinitrobenzaldehyde in dry benz. On warming with w, the nitroso compd condensed to *2,2'-Azoxybis(4,6-dinitrobenzoic acid)*, $HOOC.C_6H_2(NO_2)_2.N_2O.C_6H_2(NO_2)_2.COOH$, wh crysts, mp 245°. This compd proved to be identical with the *white compound*, which is an explosive by-product of continuous TNT manuf and whose constitution had not been previously established. The white compd was formed also from the trinitrobenzaldehyde by elimination of O. The previously report-

ed yel-brn subst, mp 229° (dec), of Sachs & Everding(Refs 1 & 2) and of Secareanu & Lupas(Ref 3) was found by Josi & Patwardhan(Ref 4) to be the crude "white compd" of above formula
*Refs*: 1)Beil **9**,417 2)F.Sachs & W.Everding,Ber **36**,962(1903) 3)S.Secareanu & I.Lupas,BullFr[5] **3**,1161(1936) & CA **30**,8181(1936) 4)S.A.Joshi & W.D.Patwardhan,CurrentSci(India) **22**,239(1953) & CA **48**,13656(1954)

**TRINITROBENZOIC ACID** (TNBAc),$(O_2N)_3C_6H_2$-$.CO_2H$; mw 257.12, N 16.34%, OB to $CO_2$-46.7%. Six isomers are possible, all of which are described in the literature:

**2,3,4(or 4,5,6)-Trinitrobenzoic Acid**, prisms(from w or benz), mp 202-3°, expl when ca 1 g or larger quant is heated; readily sol in alc or acet; sol in w or benz; diffc sol in chlf; insol in petr eth; can be prepd by oxidn of 2,3,4-TNT with nitric acid at 150-200° or with chrome-sulfuric acid ($Na_2Cr_2O_7$ or $K_2Cr_2O_7$+concd $H_2SO_4$) at 50-60°(Refs 1,2, 3,4 & 5). 2,3,4-TNBAc is converted by hot w into 2,4-dinitro-3-hydroxybenzoic acid(mp 204°), which is a mild expl(Ref 3). It forms Lead Salts(Ref 4) and a *Silver salt*, $AgC_7H_2N_3O_8$, ndls, which expl on heating above 230°(Ref 2)
*Refs*: 1)Beil **9**,(167) 2)M.Giua,AttiAccadLinceiRend [5] **23** II,486(1914) and Gazz **45** I,348 & 354 (1915) 3)R.Schmitt,MP **27**,132(1937) & CA **31**, 8199(1937) 4)M.Schaefer,MP **27**,154(1937) & CA **31**,7864(1937) 5)F.Challenger & P.H.Clapham, JCS **1948**,1612 & CA **43**,1733(1949)

**2,3,5(or 3,5,6)-Trinitrobenzoic Acid**, lfts+$2H_2O$ (from w), mp 82°(for dihydrate), 170°(for anhyd compd); can be obtd by oxidn of 2,3,5-TNT with chromic-sulfuric acid mixt at 50°(Refs 1 & 2). It is a powerful expl
*Refs:* 1)Beil **9**,(168) & [285] 2)W.Koerner & A. Contardi,AttiAccadLinceiRend [5]**24** I,893(1915) & JCS **108** I,790(1915)

**2,3,6(or 2,5,6)-Trinitrobenzoic Acid**, ndls+$2H_2O$ (from w), mp 55°(for dihydrate), 160°(for anhyd compd); can be obtd by oxidn of 2,3,6-TNT with chromic-sulfuric acid at 60-80°(Refs 1 & 2). On heating above 160° or by heating in boiling w, it is converted into 1,2,4-TNB. The 2,3,6-TNBAc is a powerful expl
*Refs*: 1)Beil **9**,(168) 2)W.Koerner & A.Contardi, AttiAccadLinceiRend [5] **25** II, 348(1916) & JCS **112** I,86(1917); Gazz **47** I,238(1917)

**2,4,5-(or 3,4,6)-Trinitrobenzoic Acid**, col lfts (from w), mp 194.5°, readily sol in alc or eth; sol in benz; v sl sol in petr eth; can be prepd by oxidn of 2,4,5-TNT by nitric acid at 150-160° or by chromic-sulfuric acid at 50-60°(Refs 1 & 2). The 2,4,5-TNBAc is converted by boiling w into 2,4-dinitro-5-hydroxybenzoic acid(mp 188°), a mild expl(Ref 3). It forms a *Lead salt*, ,PB$(C_7H_2N_3O_8)_2$ which dfgrs at 170°(Refs 3 & 4) and a *Silver salt*, $AgC_7H_2N_3O_8$, yel cryst pdr(from w), which expl on heating(Ref 2)
*Refs*: 1)Beil**9**,(168) 2)M.Giua,AttiAccadLinceiRend[5] **23**II,488(1914) & Gazz **45** I,350 & 355 (1915) 3)R.Schmitt,MP **27**,150(1937) & CA **31**, 8199(1937) 4)M.Schaefer,MP **27**,154(1937) & CA **31**,7864(1937)

**3,4,5-Trinitrobenzoic Acid**, grn-yel ndls+$(C_2H_5)_2$-O(from eth), mp 168°(dec); can be obtd by oxidn of 3,4,5-TNT with chromic-sulfuric acid at 60° (Refs 1 & 2), It is converted by boiling w into *3,5-Dinitro-4-hydroxybenzoic Acid*, a mild expl
*Refs*: 1)Beil **9**,(168) 2)W.Koerner & A.Contardi, AttiAccadLinceiRend [5] **23** II,467(1914) & JCS **108** I,875(1915)

**2,4,6-Trinitrobenzoic Acid**, yel rhmb cryst(from w), mp 228.5-229°(dec), bp dec into $CO_2$ and 1,-3,5-TNB; $Q_e^v$667.7kcal/mol & $Q_f^v$ 95.1kcal/mol (Ref 23); sol in w 2.05% at 23.5° & 4.18% at 50° (2,4,6-TNBAc dec in boiling w into 2,4,6-TNB and $CO_2$); sol at 25° in et acet 21.05, acet 22.12, 95% alc 27.53, abs alc 26.59, methanol 50.60, benz 0.308, chlf 0.371, anhyd ether 14.71, $CS_2$ 0.07, $CCl_4$ 0.07 and toluene 0.376%(Ref 5); thermal decompn in various solvs was studied by Moelwyn-Hughes & Hinselwood(Ref 6) over temp range of 70°; its dissocn constant in ethanol at 35° is 1.7 x $10^{-4}$ and Q activation 27kcal/mol (Ref 15); concd $NH_3$ causes immed decompn(Ref 7); elec conductivity was studied by Radulescu & Jula(Ref 8) and by Phillips & Lowy(Ref 12); absorption spectra in various solvs were detd by Radulescu & Alexa(Ref 11); molar refraction by Radulescu et al(Ref 16); and its spectroscopic data(UV, visible & IR) and polarographic measurements were detd by Perret & Holleck(Ref 28)

TNBAc can be prepd by the oxidn of 2,4,6-TNT with chromic-sulfuric acid mixt as 40-50°(Refs 1, 13 & 19) and is also formed in the photochemical decompn of TNT(Refs 4 & 13), as well as during the manuf of TNT, as a result of its oxidn by nitric acid. Methods of prepn are also described by Brown(Ref 20) and by Kastens & Kaplan(Ref 25). Since small amts of TNBAc form during the nitration of toluene to TNT, and in the presence of moisture react with metals to form trinitrobenzoates, TNBAc must be removed from crude TNT. This can be accomplished by washing the TNT

with hot w, followed by the sellite treatment of TNT. According to Krauz & Turek(Ref 4), all metallic trinitrobenzoates, except the Hg compds, are sensitive expls and even in small quants considerably increase the sensitiveness of TNT. Therefore, the possibility of such salts being formed must be avoided

*2,4,6-TNBAc Explosive Properties.* It is about as powerful & brisant an expl as TNT; *Sensitivity to Impact* is comparable to that of TNT; its *Ballistic Mortar* value is 98% TNT; and its *Thermal Stability* is somewhat lower than that of TNT as shown by Heat and Vac Stab tests(Refs 17 & 19a) Because of the hygroscopic nature of TNBAc, it forms expl salts with the following metals: aluminum, barium, bismuth, copper, iron, lead, mercury silver & tin, all of which(except Al, Bi & Sn) are cryst substs and all expl on shock or by heat(Ref 4). Props of the more important salts are as follows:

*Barium 2,4,6-Trinitrobenzoate*, $Ba(C_7H_2N_3O_8)_2$, dk brn-red ppt, mp expl; extremely diffc sol in w, giving a red color(Refs 1,3 & 4). *Lead 2,4,6-Trinitrobenzoate*, $[(O_2N)_3C_6H_2COO]_2Pb$, ndls(from dil alc) or lt cream solid, mp chars at 130° & deflgr at 260°(Ref 17); expl at 179°(Ref 13); readily sol in cold w, diffc sol in alc; can be prepd by reacting 2,4,6-TNBAc with lead acetate in alc (Refs 4,14 & 17). It is an expl about 70% as powerful as TNT and is comparable in sensitivity to tetryl(Ref 17). The *Lead+Lead Oxide salt*, $Pb(C_7H_2N_3O_8)_2+PbO$, red pdr, expl on contact with a hot wire and by impact or friction(Ref 1). Brün (Ref 10) patented the use of the *Nitroic Lead Salt of TNBAc* or of *Lead Dinitrobenzoate Nitrate* in priming compns. *Nickel 2,4,6-Trinitrobenzoate*, $Ni(C_7H_2N_3O_8)_2$, col cryst powd, weak expl; readily sol in w, diffc sol in alc(Ref 4). *Silver 2,4,6-Trinitrobenzoate*, $Ag(C_7H_2N_3O_8)$, lfts or laminates, mp expl above 230°; diffc sol in alc or w (Refs 2 & 4). *Thallous 2,4,6-Trinitrobenzoate*, $Tl(C_7H_2N_3O_8)$, cryst ppt, mp 160-3°(dec); was prepd from 2,4,6-TNBAc and thallous hydroxide; in boiling pyridine soln, the salt decarboxylates smoothly to 1,3,5-TNB and thallous oxalate. The Tl salt reacts further with TlOH giving a blood -red complex of uncertain compn which exploded on heating(Refs 18 & 22)

2,4,6-TNBAc forms numerous esters and nitro derivs thereof, as described in the literature. Some of these will be discussed under Phenylbenzoate and Derivatives. Parks & Farthing(Ref 21) reduced 2,4,6-TNBAc to a compd, $C_7H_5N_3O_6$, mp 218°(dec) and they also obtd other unstable derivs. Identification of TNBAc by reaction with std chromous chloride soln is suggested by Bottei & Furman(Ref 27). Krauz & Stepanek(Ref 9) proposed separating 2,4,6-TNBAc from PA by pptg the acid as the silver salt, $Ag(C_7H_2N_3O_8)$, and PA as the nitrone picrate, $C_6H_2(NO_2)_3OH.C_{20}H_5N_4$

*Uses.* In addn to its uses as an expl, Yoshinaga(Ref 24) patented the use of 2,4,6-TNBAc, alone or mixed with a fatty acid, lithophone, talc & pine tar as an aide in the vulcanization of rubber compds. Smith & Wilkins(Ref 26) proposed the use of highly purified 2,4,6-TNBAc as a primary std in acidimetry

*Refs*: 1)Beil **9**,417,(168) & [285] 2)F.Tiemann & W.E.Judson,Ber **3**,224(1870) 3)A.Hantzsch & H.Kissel,Ber **32**,3143(1899) 4)C.Krauz & O.Turek ChemAge **13**, 392(1925) & CA **20**,824(1925) and Chim&Ind(Paris),Spec No Sept 1926,pp 543-7 & CA **21**,651(1927) 5)L.Desvergnes,MonSci [5] **16**, 201(1926) & CA **21**,740(1927) 6)E.A.Moelwyn -Hughes & C.N.Hinselwood,PrRoySoc **131A**,186 (1931) & CA **25**,3226(1931) 7)S.Secareanu,BullFr **53**,1395(1935) & CA **28**,4048(1934) 8)D.Radulescu & O.Jula,ZPhysChem **B26**,395(1934) & CA **28**,7136 (1934) 9)C.Krauz & J.Stepanek,ChemObzor **9**,137 (1934) & CA **28**,7203(1934) 10)W.Brün,USP 1971-031(1934 & CA **28**,6314(1934) 11)D.Radulescu & V.Alexa,BullSocChim(Romania) **17**, 69(1935) & CA **30**,2111(1936) 12)J.Phillips & A.Lowy,Trans ElectrochemSoc **71**,10pp(Preprint)(1937) & CA **31**,2105(1937) 13)R.Schmitt,MP **27**,150(1937) & CA **31**,8199(1937) 14)M.Schaefer,MP **27**,154(1937) & CA **31**,7864(1937) 15)F.H.Verhoek,JACS **61**, 186(1939) & CA **33**,2023(1939) 16)D.Radulescu et al,BullSocStiinteCluj **9**,215(1939) & CA **33**,9298 (1939) 17)R.McGill,OSRD Rpt **830**(1942),p 35 18)R.K.Abbott,Jr,IowaStateCollJSci **18**,3(1943) & CA **38**,62(1944) 19)OrgSynthCollVol **2**(1943),95 19a)Blatt,OSRD **2014**(1944) 20)D.J.Brown,JSCI **66**,168(1947) & CA **41**,7387(1947) 21)G.D.Parks & A.C.Farthing,JCS **1948**,1277 & CA **43**,592 (1949) 22)H.Gilman & R.K.Abbott,Jr,JACS **71**, 659(1949) & CA **43**,3352(1949) 23)L.Médard & M.Thomas,MP **31**,179,189 & 196(1949) & CA **46**, 11684(1952) 24)H.Yoshinaga,JapP 1543(1950) & CA **46**,8410(1952) 25)M.L.Kastens & J.F.Kaplan IEC **42**,402(1950) & CA **44**,4441(1950) 26)G.F. Smith & D.H.Wilkins,AnalChimActs **8**,209(1953) & CA **47**,12102(1953) 27)R.S.Bottei & N.H.Furman,AnalChem **27**,1182(1955) & CA **49**,14580 (1955) 28)G.Perret & L.Holleck,ZElektrochem

60,463(1956) & CA 50,16385(1956)

**2,4,6-Trinitrobenzoic Acid, Anhydride or Trinitrobenzoylanhydride**, $[(O_2N)_3C_6H_2.CO]_2O$; mw 496.22, N 16.94%, yel ndls, mp 270° (dec); sl sol in benz. Was obtd, together with 2,4,6-trinitrobenzoylchloride, on treating 2,4,6-trinitrobenzoic acid with a mixt of phosphorus pentachloride and oxychloride. Care should be taken to prevent overheating, which might result in an expl. Another method of prepn is given in Ref 3

*Refs*: 1)Beil 9,417 2)J.J.Sudborough, JCS 67,600 (1895) 3)R.Reed,Jr, JACS 77,3404-R(1955) & CA 50,4071(1956)

**Benzoic Acid Amide.** See Benzamide

**Benzoic Acid, Benzyl Ester of.** See Benzylbenzoate

**Benzoic Acid Chloride.** See Benzoylchloride

## BENZOIC ACID DIAZONIUMHYDROXIDE AND DERIVATIVES

*Benzoic Acid Diazoniumhydroxide* (called Benzoesäure-diazoniumhydroxid in Ger), $HO_2C.C_6H_4.N(:N).OH$; mw 166.13, N 16.86%. Known primarily in the form of its salts, nitro compds, esters and addn compds. These exist as 2(or ortho)-, 3(or meta)- and 4(or para)-diazoniumhydroxide derivs (see below)

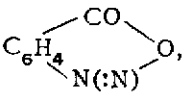
*Refs*: Beil 16,544,546 & 549 & [297 & 298]

### Salts and Other Derivatives of Benzoic Acid-2-Diazoniumhydroxide

*Benzoic Acid-2-Diazoniumhydroxide* may be considered the parent compd of its salts, some of which are expl(Ref 1). Eg: *Chloride Addn Compd*, $HO_2C.C_6H_4.N_2.Cl+C_7H_4N_2O_2$, wh ndls, mp expl on heating; likely to decomp in the solid state or in soln(Ref 6); *Dichloroiodide*, $HO_2C.C_6H_4.N_2.Cl_2I$, brn-yel lfts, mp ca 108-9° (decomp & weakly expl)(Ref 3); *Nitrate*, $HO_2C.C_6H_4.N_2.O.NO_2$, almost col tablets or prisms, darkens in the light, mp expl violently on heating or by impact(Refs 4 & 5); *Nitrate Addn Compd*, $HO_2C.C_6H_4.N_2.O.NO_2+C_7H_4N_2O_2$, wh prisms or ndls(from alc+eth), mp expl on heating ca 95°, expl by impact and dec on exposure to light(Refs 2,4, & 5)

*Refs*: 1)Beil 16,545 & [297] 2)P.Griess,Ann 117, 39(1861) 3)(?).Froehlich,GerP 87970; Frdl 4,1102 (1874) 4)P.Griess,Ber 9,1653(1876) 5)A.Hand, Ann 234,147-9(1886) 6)A.Hantzsch & W.B.Davidson,Ber 29,1535(1896)

**Anhydro-(benzoic acid-2-diazoniumhydroxide)**, called Diazoniumanthranilic Acid in JCS 70 I, 541 (1896),



mw 148.12, N 18.91%, wh ndls, expl violently even when rubbed; insol in eth; its aq soln dec slowly with the formation of salicylic acid; can be prepd by diazotizing anthranilic acid

*Refs*: 1)Beil 16,546 2)A.R.Hantzsch & W.B. Davidson,Ber 29,1536(1896) & JCS 70 I,541(1896)

**Benzoic Acid-2-diazonium-(4-nitrophenyl)-ether**, $HO_2C.C_6H_4.N(:N).O.C_6H_4.NO_2$, mw 287.23, N 14.63%; wh lfts(from alc), mp expl violently on heating; mod sol in cold alc; insol in eth; dec in boiling w; can be prepd by treating a cold, concd, sl alkaline soln of 4-nitrophenol with the nitrate of 2-diazobenzoic acid

*Refs*: 1)Beil 16,546 2)P.Griess,Ber 17,340(1884) & JCS 46 II,1014(1884)

**Benzoic Acid-2-diazoniumthiophenylether**, $HO_2C.C_6H_4.N(:N).S.C_6H_5$; mw 258.30, N 10.85%; yel ppt, mp ca 60° with expln; dissolves unchanged in cold dil NaOH or Na carbonate; can be obtd by gradually adding a soln of 2-diazobenzoic acid chloride to a cooled dil soln of sodium thiophenate

*Refs*: 1)Beil 16,546 2)C.Graebe & O.Schultess, Ann 263,3(1890) & JCS 60 II,1058(1891)

### Salts and Other Derivatives of Benzoic Acid-3-Diazoniumhydroxide

*Benzoic Acid-3-diazoniumhydroxide* may be considered the parent compd of its salts, some of which are expl(Ref 1): *Chloride*, $HO_2C.C_6H_4.N_2.Cl$, yel-wh cryst, mp expl 105°, but when carefully heated melts at 145-150°; prepd by the action of amyl nitrate on an alc soln of the hydrochloride of 3-amino-benzoic acid(Ref 5); *Nitrate*, $HO_2C.C_6H_4.N_2.O.NO_2$, wh prisms, mp expl violently on heating; diffc sol in cold w; can be prepd by passing nitrogen oxide gases into a concd soln of 3-aminobenzoic acid in cold aq or alc $HNO_3$(Ref 2) or by the action of nitrogen oxide gases on a cold alc soln of 3-aminobenzoic acid in sulfuric acid(Ref 4); *Chloroaurate*, $HO_2C.C_6H_4.N_2.Cl+AuCl_3$ and *Chloroplatinate*, $2(HO_2C.C_6H_4.N_2.Cl+PtCl_4)$, salts were prepd also by Griess(Refs 2 & 3) and are probably expl

*Refs*: 1)Beil 9,546 &[298] 2)P.Griess,Ann 120, 126(1861) 3)P.Griess,JPraktChem 1,102 Foot-

note (1870) 4)A.Hand,Ann **234**,152(1886) 5)H. Euler,Ann **325**,302(1902) & JCS **84** I,299(1903)

**5-Azidobenzoic Acid-3-diazoniumhydroxide**, $HO_2C.C_6H_3(N_3).N(:N).OH$; mw 207.15, N 33.18%. It is known in the form of salts, some of which are probably expl: *Nitrate*, $HO_2C.C_6H_3(N_3).N_2.ONO_2$, wh prisms, obtd by treating a cold, highly concd sol of 5-azido-5-aminobenzoic acid with nitrous acid; *Platinum Chloride salt*, $2[HO_2C.C_6H_3(N_3).N_2.Cl]+PtCl_4$, yel cryst, very diffc sol in w; *Tribromide*, $HO_2C.C_6H_3(N_3).N_2.Br_3$, yel cryst, obtd by treating a concd soln of the nitrate with $Br_2$ & HBr. Their expl props were not investigated

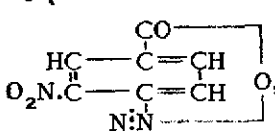
*Refs*: 1)Beil **16**,548 2)P.Griess,Ber **21**,1563 (1888) & JCS **54** II,827(1888)

**Salts and Other Derivatives of Benzoic Acid -4-Diazoniumhydroxide**

*Benzoic Acid-4-diazoniumhydroxide* may be considered the parent compd of its salts, some of which are expl(Ref 1): *Chloride*, $HO_2C.C_6H_4.N_2.Cl$, wh ndls, mp expl on heating(Refs 3 & 5); *Nitrate*, $HO_2C.C_6H_4.N_2.O.NO_2$, wh ndls or prisms, mp expl on heating; readily sol in w(Refs 2 & 4); and *Compound*, $C_{13}H_{18}N_4O_4$, pale-yel powd(from benz by pptn with ligroin), readily sol in hot alc or benz; insol in ligroin or eth; was prepd by treating 1 mole of benzoic acid -4-diazonium chloride with an alkaline soln of 2 moles of acetoxime. Its *Silver salt*, $AgC_{13}H_{17}N_4O_4$, expl violently on heating(Ref 6)

*Refs*: 1)Beil **16**,549 & [298] 2)I.Remsen & R.O. Graham,AmChemJ **11**,326(1889) & JCS **56** II,975 (1889) 3)J.W.Marshall,Ber **28**,338(1895) & JCS **68** I,239(1895) 4)G.F.Weida,AmChemJ **19**,556 (1897) & JCS **72** I,563(1897) 5)H.Euler,Ann **325**, 302(1902) & JCS **84** I,299(1903) 6)H.W.Bresler et al,Ber **39**,879(1906) & JCS **90** I,322(1906)

**Anhydro-(3-nitrobenzoic acid-4-diazoniumhydroxide)**,

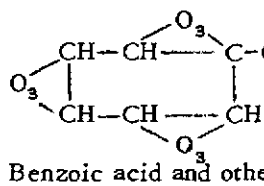


O, mw 193.13, N 21.76%; lt yel lfts, mp expl violently on heating or impact; almost insol in cold alc; can be obtd by treating cold 3-nitro-4-aminobenzoic acid with abs alc saturated with nitrous acid. The compd, in boiling alc, gives 3-nitro-benzoic acid

*Refs*: 1)Beil **16**,550 2)H.Salkowski,Ann **173**,63 (1874)

**Benzoic Acid Hydrazonium Hydroxide.** Incorrectly listed in Vol 1,p 630-L for 3rd item from bottom which should read Azidobenzoic Acid Diazonium Hydroxide

**Benzoic Acid Triozonides,**



mw 266.12, O 66.16%; Benzoic acid and other aromatic substs add on a molecule of ozone($O_3$) at each of the double bonds of the benz nucleous to form triozonides. These compds are wh camphor-like substs at low temps and oils at RT. They are very unstable and tend to dec with expl violence at RT. In water they dec to form, probably, 1 mol of oxygen, 2 mols glyoxal, 1 mol formic acid, and 1 mol of a dibasic acid

Benzoic acid triozonide was prepd by treating the acid in chlf and $CCl_4$ at 0-15° with ozone for 20 hrs. One sample of the triozonide exploded in a desiccator. This triozonide was less stable than that of either benzylic acid, $C_6H_5.CH_2.COOH$ or of phenethylic(phenyl-β-ethyl) acid, $C_6H_5.CH_2.CH_2.COOH$, which were obtd in lower yields

*Refs*: 1)Beil- not found 2)H.Ruppe & H.Hirschmann,Helv **14**,54(1931) & CA **25**,1820(1931)

**Benzol** (*e*). Same as Benzene

**Benzomethylanilide.** See Benzotoluide

**Benzonitrile and Derivatives**

*Benzonitrile or Phenyl Cyanide* (called Benzoesäurenitril, Benzonitril of Phenylcyanid in Ger), $C_6H_5.CN$; mw 103.12, N 13.58%; transparent col oil with almond-like odor, mp -12.9°, bp 191°, d 1.01 at 15°; highly toxic but somewhat less so than cyanogen or hydrocyanic acid(Ref 2). Its other props & prepn are given in Ref 1. Benzonitrile forms numerous salts and addn compds

*Refs*: 1)Beil **9**,275,(121) & [196] 2)Sax(1957), 350

**Azidobenzonitrile**, $N_3.C_6H_4.CN$; mw 144.13, N 38.87%. Three isomers are described in the literature: *2-Azido*, lt,sensitive, yel lfts(from petr eth), sinters ca 51°, mp 58°; *3-Azido*, lt yel ndls

(from alc), mp 57°; and *4-Azido*, ndls (from alc), mp 70°. Their other props & prepn are given in Beil **9**,418,419 & [169]

*Mononitrobenzonitrile*, $O_2N.C_6H_4.CN$; mw 180.12, N 15.55%. Three isomers are described in the literature: *2-Nitro*, ndls(from w or glac AcOH), mp 110°(Ref 1) *3-Nitro*, ndls(from w), mp 115-118°, sublimes on heating below mp(Ref 2) and *4-Nitro*, yel lfts(from alc), mp 146-149°(Ref 3). Their other props & prepn are given in the Refs

*Refs*: 1)Beil **9**,374 & [246] 2)Beil **9**, 385,(156) &[254] 3)Beil **9**,397,(164) & [273]

**Dinitrobenzonitrile**, $(O_2N)_2C_6H_3.CN$; mw 193.12, N 21.76%. The following isomers are described in the literature: *2,3-Dinitro*, lt buff lfts(from aq alc), mp 97-8°(Ref 8); *2,4-Dinitro*, brn-yel lfts(from alc), mp 103-5°(Refs 1,4 & 7), its reactions(Refs 4 & 5) and eutectics(Ref 7); *2,6-Dinitro*, lt brn ndls(from alc), mp 145°(Ref 2); *3,4-Dinitro*, lt yel ndls(from alc), mp 92°(Ref 6); and *3,5-Dinitro*, yel monocl prisms(from alc), mp 127-130°(Refs 3 & 9). Their expl props were not investigated

*Refs*: 1)Beil **9**,412 & [279] 2)Beil **9**,413 & [167] 3)G.M.Bennett & R.L.Wain,JCS **1936**,1111 & CA **30**,7558(1936) 4)F.R.Storrie,JCS **1937**,1746 & CA **32**,522(1938) 5)C.W.N.Holmes & J.D.Loudon, JCS **1940**,1521 & CA **35**,1776(1941) 6)H.Goldstein & R.Voegeli,Helv **26**,1126(1943) & CA **38**, 78(1944) 7)H.Rheinboldt & M.Perrier,ChemBer **85**,110 & 127(1952) & CA **46**,7554(1952) 8)D.L. Vivian et al,JOC **20**,800(1955) & CA **50**,7813 (1956) 9)A.V.Kirsanov & R.G.Makitra,ZhObshch-Khim **26**,907(1956) & CA **50**,14633(1956)

*Note:* Higher nitro derivs of benzonitrile were not found in Beil or in CA thru 1956

**Benzonitrile-3-diazoniumhydroxide**, $NC.C_6H_4.N(:N).OH$; known only in the form of salts. Its *Nitrate*, $NC.C_6H_4N_2.O.NO_2$, ndls or prisms, is expl

*Ref*: Beil **16**,548

**Benzooxytriazine.** See under Benzotriazine

### Benzophenone and Derivatives

*Benzophenone or Diphenylketone* (also called α-Oxodiphenylmethane or Benzoylbenzene)(called α-Oxo-diphenylmethan, Diphenylketon, Benzophenon, α-Oxo-ditan or Benzoylbenzol in Ger), $C_6H_5.CO.C_6H_5$; mw 182.12, O 8.78%; wh rhmb crysts with rose-like odor; mp α-form 49°, β-form 26°, γ-form 47°; bp 305°, vap press 1mm at 108°; d α-form 1.098 at 50°, β-form 1.108°; toxicity details are unknown(Ref 4). Its other props & prepn are given in Refs 1,2 & 3

*Refs*: 1)Beil **7**,410,(218) & [349] 2)A.N.Sachanen & F.D.Caesar,USP 2 528 789 (1950) & CA **45**,2981(1951) 3)E.B.Bengtsson,SwedP 137686 (1952) & CA **48**,2110(1954) 4)Sax(1957),350

**Azidobenzophenone**, $C_6H_5.CO.C_6H_4.N_3$; mw 223.23, N 18.83%. The following isomers are described in the literature: *2-Azido*, lt yel ndls(from abs alc), mp 36-8°, dec with a puff on contact with sulfuric acid; prepd by diazotizing o-aminobenzophenone and adding Na azide to the diazonium soln(Ref 2) and the *4-Azido*, pale yel lfts(from eth), mp 74.5°; prepd by adding ammonia to the diazoniumperbromide of 4-aminobenzophenone (Ref 1). Their expl props were not detd

*Refs*: 1)Beil **7**,(232) 2)P.A.S.Smith et al,JACS **75**,6336(1953) & CA **49**,7571(1955)

**Benzophenonediazide**, $C_6H_5.C(N_3)_2.C_6H_5$; mw 250.26, N 33.58%; crysts(from MeOH), mp 42°; unchanged by boiling w or dil alks; dec into N-α-diphenyltetrazole when distilled in vac or when heated in amyl eth and $CO_2$ atm; reacts explosively with concd sulfuric acid, even in the cold. Was prepd from benzophenonedichloride and Na azide in acet soln. This compd is considered quite stable and its sensitivity to shock is only sl greater than that of PA

*Refs* 1)Beil- not found 2)S.Götzky,Ber **64**,1558 (1931) & CA **25**,4543(1931)

*Mononitrobenzophenone*, $C_{13}H_9NO_3$, mw 227.21, N 6.17%. The *2-Nitro*, monocl prisms, mp 105°; *3-Nitro*, ndls(from alc), mp 95°; and *4-Nitro deriv* lfts(from abs alc), mp 138°, are described in Beil **7**,425,426,(230) & [362]

**Dinitrobenzophenone** $C_{13}H_8N_2O_5$; mw 272.21, N 10.29%. The following isomers are described in the literature: *2,2'-Dinitro*, col ndls(from toluene or glac AcOH), mp 188-9° *2,3'-Dinitro*, prisms (from toluene), mp 126° *2,4'-Dinitro*, col prisms (from glac AcOH), mp 196-7° *3,3'-Dinitro*, col lfts(from glac AcOH) or cryst(from MeEt ketone), mp 155° *3,4'-Dinitro*, col ndls(from glac AcOH), mp 172-5° *4,4'-Dinitro*, col ndls(from glac AcOH) or prisms(from Et acet), mp 189° and *3,5-Dinitro deriv*, yel prisms(from alc), mp 131°

*Ref:* Beil **7**,427,428,(231) & [364]

**Trinitrobenzophenone**, $C_{13}H_7N_3O_7$; mw 317.21, N 13.25%. Only the *3,5,3'-trinitro deriv* is described in the literature: col crysts, mp 159°; diffc sol in alc; was prepd by heating 3,5-dinitrobenzophenone with dil nitric acid for 6 hrs. Its expl props were not investigated
*Refs*: 1)Beil- not found 2)F.Bardone,CR **236**, 830(1953) & CA **48**,2671(1954)

**Tetranitrobenzophenone**, $C_{13}H_6N_4O_9$; mw 362.21, N 15.47%. Two isomers are described in the literature:
*2,4,2',4'-Tetranitrobenzophenone*[called Bis(2,4-dinitro-phenyl)-keton in Ger)], yel prisms, mp 232°; was prepd by adding chromic oxide to tetranitrodiphenylmethane in glac AcOH and boiling the soln for 2 ½ hrs or longer(Refs 1 & 2). It was found to be less powerful and less brisant than PA(Ref 3)
*Refs*: 1)Beil **7**,429 & [365] 2)K.Matsumara,JACS **51**,818(1929) & CA **23**,1904(1929) 3)Blatt,OSRD **2014**(1944), under Nitro Compounds
*3,5,3',5'-Tetranitrobenzophenone*, col crysts, mp 250°, sl sol in alc; was prepd by treating 3,5,3'-trinitrobenzophenone with fuming nitric-sulfuric acid mixt(Ref 2). Its expl props were not detd
*Refs*: Beil- not found 2)F.Bardone,CR **236**,830 (1953) & CA **48**,2671(1954)
*Note*: Higher nitro derivs were not found in Beil or in CA thru 1956

**Benzophenonecarboxylic Acid.** See Benzoylbenzoic Acid

**Benzophenone Peroxide.** Same as Dibenzophenone Peroxide

### Benzophenoxazine and Derivatives

*Benzophenoxazine*, $C_{16}H_{11}NO$; mw 233.26, N 6.01%. According to Beil(Ref 1), this compd exists as the following isomers: 1,2-, 2,3 and 3,4-Benzophenoxazine. CA(Refs 2 & 3) also lists 3 isomers but calls them: 5H-[*a*], 9H-[*a*] and 12H-[*a*]-Benzophenoxazines
*Ref*: 1)Beil **27**,80 & 81 & (240,241) 2)CA Decennial Index, Subject(1937-46),p 4289 3)Ibid(1947-56),p 1757a
*Mononitrobenzophenoxazine*, $C_{16}H_{10}N_2O_3$; mw 278.26, N 10.0%. Two isomers are described in Beil: *7(?)-Nitro-2,3-benzophenoxazine*, brn-red ndls(from alc), mp 222-3°(dec); and *2-Nitro-3,4-benzophenoxazine*, violet flakes, mp dec at RT and dec rapidly on heating to ca 115° or on heating in soln
*Ref*: Beil **27**,(240) & [47]
*Dinitrobenzophenoxazine*, $C_{16}H_9N_3O_5$; mw 323.26 N 13.00%. Three isomers are described in Beil: *5,7-Dinitro-1,2-benzophenoxazine*, brn-red crysts *5,7-Dinitro-2,3-benzophenoxazine*, brick-red crysts (from toluene), mp ca 313°(dec) and *5,7-Dinitro-3,4-benzophenoxazine*, brn-red ndls, mp ca 279° (dec)
*Ref*: Beil **27**,[46 & 47]
*Trinitrobenzophenoxazine*, $C_{16}H_8N_4O_7$, not found in Beil or in CA thru 1956
**x,x,x,x-Tetranitro-2,3-benzophenoxazine**, $C_{16}H_7N_5O_9$; mw 413.26, N 16.95); dk-red lfts or tablets (from aniline), mp expl on heating; sol in dil alkali hydroxide with a violet col; sol in concd sulfuric acid giving a blood-red col; was prepd by treating 10-acetyl-2,3-benzophenoxazine with fuming nitric acid in ice-cold glac AcOH. It forms a dk-brn Na salt
*Refs*: 1)Beil **27**,(240) 2)F.Kehrmann & A.A.Neil, Ber **47**,3105(1914) & JCS **108** I,304(1915)

### Benzophenyltriazole and Derivatives

*Benzophenyltriazole or Phenylbenzotriazole*, $C_{12}H_9N_3$; mw 195.22, N 21.23%. (Several isomers of either α-v(or 1,2,3)-triazole or β-v(or 2,3,1)-triazole are described in Beil **26**,39 & [18,46]
*Mononitrobenzophenyltriazole*, $C_{12}H_8N_4O_2$; mw 240.22, N 23.3%. Several isomers are described in the literature
*Refs*: 1)Beil **26**,39,44,(11) & [26] 2)K.Fries et al,Ann **511**,247(1934) & CA **28**,5447(1934)

**Dinitrobenzophenyltriazole**, $C_{12}H_7N_5O_4$; mw 285.22, N 24.56%. Several isomers are described in the literature(Refs 1-4). The isomer *Benzo-1-(2',4'-dinitrophenyl)-α-v(or 1,2,3)-triazole*, $HC{-}CH{=}C{-}N[C_6H_3(NO_2)_2]{-}N{=}$ / $HC{-}CH{=}C{-}$ N, reported to defgr with evoln of flame when heated above its mp 186-7°; was prepd by treating an alc soln of dinitroaminodiphenyl hydrochloride with Na nitrite (Ref 2)
*Refs*: 1)Beil **26**,44,50 & (10,11) 2)W.Borsche & D.Rantscheff,Ann **379**,169(1911) 3)K.Fries et al, Ann **511**,247(1934) & CA **28**,5447(1934) 4)R. Andrisano & D.Dalmonte Casoni,CA **41**,723(1947)

**Trinitrobenzophenyltriazole**, $C_{12}H_6N_6O_6$; mw 330.22, N 25.45%. The following isomer is described in the literature: *5-Nitrobenzo-2-(2',4'*

*-dinitrophenyl)-β-ν(or 2,3,1)-triazole* (called p-Nitro-o-phenylen-azimido-o-p-dinitrobenzol by Willgerodt), $\begin{array}{l} HC{=}CH{-}C{=}N{-}N[C_6H_3(NO_2)_2]; \\ O_2N.C{=}CH{-}C{=}N \end{array}$ yel ndls(from AcOH or alc), mp 238°. It was prepd by heating 5-nitrobenzo-2-phenyl-triazole with fuming nitric acid(Refs 1 & 2). Its expl props were not investigated

*Refs:* 1)Beil **26**,45 2)C.Willgerodt et al,JPrakt-Chem **42**,130(1890) & **55**,390(1897)

**Tetranitrobenzophenyltriazole,** $C_{12}H_5N_7O_8$; mw 375.22, N 26.13%. The following isomer is described in the literature:

*4,6-Dinitrobenzo-2-(2',4'-dinitrophenyl)-β-ν(or 2,3,1)-triazole* (called Tetranitro-phenylazimido-benzol by Willgerodt), $\begin{array}{l} O_2N.C{=}C{-}C{=}N{-}N{-} \\ HC{=}C(NO_2){-}C{=}N \end{array}$ $[C_6H_3(NO_2)_2]$; lt yel crysts(from AcOH), mp 195-6°; sol in AcOH, benz or toluene; diffc sol in chlf, eth or alc; insol in w. Can be prepd by heating 4,6-dinitrobenzo-2-phenyl-triazole with concd nitric-sulfuric acid. Its expl props were not investigated

*Refs:* 1)Beil **26**,50 2)C.Willgerodt,Ber **25**,2663 (1892)

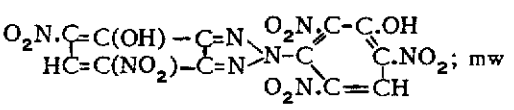
**Benzophenyltriazole, Dihydro- and Derivatives**

*Dihydroxybenzophenyltriazole* (called Dioxy-phenylbenztriazol in Ger), $C_{12}H_9N_3O_2$, mw 227.22, N 18.49%. Several isomers are described in Beil **26**,(34)

*Dinitrodihydroxybenzophenyltriazole,* $C_{12}H_7N_5O_6$; mw 317.22, N 22.08%. One isomer, *2-(3, 5-Dinitro-2,-4-dihyroxy-phenyl)-benzotriazole,* is described in Beil **26**,[19]

*Trinitro-*, $C_{12}H_6N_6O_8$ and *Tetranitro-*, $C_{12}H_5N_7O_{10}$,*Derivatives of Dihydroxybenzophenyltriazole,* were not found in Beil or in CA thru 1956

**Pentanitrodihydroxybenzophenyltriazole** {called *Pentanitrodihydroxyphentriazole* or *5,7-Dinitro-2,-1,3-benzotriazol-4-o1,2-(3-hydroxypicryl)* in CA and called 5,7-Dinitro-4-oxy-2-[2.4.6-trinitro-3-oxyphenyl]-benztriazol in Ger},



; mw 452.22, N 24.78%. Brn amor pdr, dec 176-180°, deflgr ca 275°; easily sol in alc, AcOH & acet; diffc sol in hot w; nearly insol in benz. Was prepd by reduction of azopicric acid(hexanitro-azophenol) with NaSH in w

*Refs:* 1)Beil **26**,[61] 2)K.Elbs & O.H.Schaaf, JPraktChem **120**,17(1928) & CA **22**,4508(1922)

**Benzophenyltriazole, Hydroxy-and Derivatives**

*Hydroxybenzophenyltriazole* (called Oxyphenyl-benztriazol in Ger), $C_{12}H_9N_3O$; mw 211.22, N 19.90%. Several isomers are described in Beil **26**,40(28-9) & [18,61-2]

*Mononitrohydroxybenzophenyltriazole,* $C_{12}H_8N_4O_3$; mw 256.22, N 21.87%. One isomer 2-phenyl-nitro-5-hydroxy-benzotriazole is described in Beil **26**,)30)

*Dinitrohydroxybenzophenyltriazole,* $C_{12}H_7N_5O_5$; mw 301.22, N 23.25%- not found in Beil, but its isomer 2-Phenyl-4,6-dinitro-benzotriazole-1-oxide, lt yel crysts, mp 195-6°, is listed in Beil **26**,50

*Trinitrohydroxybenzophenyltriazole,* $C_{12}H_6N_6O_7$; mw 346.22, N 24.28%- not found in Beil, but its isomer *5-Nitro-2-(2,4-dinitrophenyl)-benzotriazole-3-oxide,* yel crysts, mp 224°, is listed in Beil **26**, 45

*Tetranitrohydroxybenzophenyltriazole,* $C_{12}H_5N_7O_9$; mw 391.22, N 25.06%- not found in Beil, but its isomer *2-(2,4-Dinitro-phenyl)-4,6-dinitro-benzotriazole-1-oxide,* yel crysts, dec 192°, is listed in Beil **26**,51

**Benzopyrazoles.** See under Aminoindazoles, Vol 1,p A224-L

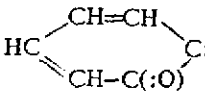
**Benzopyrylium Compounds.** A group of compds derived from benzopyran, the O of which is assumed to be tetravalent(Ref 2). Structural formulas of the compds and salts studied are given in Refs 1 & 3. Shriner & Moffett(Ref 1) published several articles reporting their investigations of benzopyrylium compds. Some benzopyrylium derivs, such as substituted *2,3-Diphenylbenzopyrylium perchlorates,* proved to be expl. Care must be exercized during their prepn and in the prepn of *Phenylflavylium perchlorates* to prevent expln(Ref 3)

*Refs:* 1)R.L.Shriner & R.B.Moffett,JACS **61**, 1474(1939); **62**,2711(1940); **63**,1694(1941) & **66**, 301(1944) 2)Hackh's(1944),117 3)R.R.Otter & R.L.Shriner,JACS **73**,889(1951)

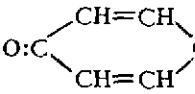
## BENZOQUINONE AND DERIVATIVES

*Benzoquinone*[Quinone; o-(or)p-Dioxybenzene; Benzenone or Dihydrodiketobenzene], $C_6H_4O_2$; mw 108.09, O 29.60%. This compd exists as the ortho and para isomers: *1,2(or o)-Benzoquinone*

[called Benzochinon-(1.2); o-Benzochinon; o-Chinon or Cyclohexadien-(1.3)-dion-(5.6) in Ger],



*bright red form*, transparent, 4-sided octagonal tablets or prisms, mp dec on standing or beginning ca 60-70°; *col form*, col prisms, mp expl occasionally, giving off grn-brn smoke; in a little ethereal soln, changes rapidly into the red form(Ref 1); *1,4(or p)-Benzoquinone* [called Benzochinon-(1.4); p-Benzochinon; p-Chinon or Cyclohexadien-(1.4)-dion-(3.6) in Ger],



yel prisms(from w, cold ligroin or petr eth), mp 115.7°, bp-sublimes; d 1.307; readily sol in hot w or ligroin; mod sol in hot w or ligroin; mod sol in cold petr eth or cold ligroin; sol in alc or eth; sl sol in cold w. Other props & prepn are given in Ref 2; toxicity is discussed in Sax(Ref 4). 1,4-Benzoquinone forms numerous addn compds and salts(Ref 3), many of which are unstable and some undoubtedly are expl

*Refs*: 1)Beil **7**,600,(337) & [566] 2)Beil **7**,609, (340) & [567] 3)Beil **7**,615,(343) & [572] 4)Sax (1957),350 & 1077

**Azido and Azido Halogen Derivatives of Benzoquinone**

**2-Azido-3,5,6-trichloro-1,4-benzoquinone,** $O:C_6Cl_3(N_3):O$; mw 252.45, N 16.64%; dk-orn ndls (from alc), mp 147-9° (turns brn at 145°), expl mildly on rapid heating; was prepd by adding 1 mol of 2,3,5,6-tetrachloro-1,4-benzoquinone to 1 mol of Na azide in glac AcOH at 100°. By slowly heating this compd near or sl above the mp, a red liq is obtd

*Refs*: 1)Beil **7**,[587] 2)A.Korczyński & St.Namyslowski,BullFr [4] **35**,1189 (1924) & CA **19**,644 (1925)

**2,5-Diazido-3,6-dichloro-1,4-benzoquinone,** $O:C_6Cl_2(N_3)_2:O$; mw 259.02, N 32.45%; vermillion crysts(from glac AcOH), mp expl violently on heating; sol in xylene with decompn; diffc sol in alc or glac AcOH; was prepd by treating 2,3,5,6-tetrachloro-1,4-benzoquinone(Chloranil) with 4 mols of Na azide in boiling glac AcOH(Ref 2) or by treating 2-azido-3,5,6-trichloro-1,4-benzoquinone with 2 mols Na azide in boiling alc(Ref 3). This compd is insensitive to friction or impact. On warming with aniline, it gives 2,5-dianilino-3,6-dichloro-1,4-benzoquinone and a small quant of a blue-black prod which expl on heating (Ref 2)

*Refs*: 1)Beil **7**, [587] 2)K.Fries & P.Ochwat, Ber **56**,1303(1923) & JCS **124** I,844(1923) 3)A. Korczyński & St.Namyslowski,BullFr [4] **35**,1190 (1924) & CA **19**,644(1925)

**2,3,5-Triazido-6-chloro-1,4(?)-benzoquinone,** $O:C_6Cl(N_3)_3:O$; mw 265.59, N 47.48%; red-violet cryst, mp-expl on heating; diffc sol in glac AcOH, but not decompd by boiling in glac AcOH; was prepd by treating 2,3,5,6-tetrachloro-1,4-benzoquinone (Chloranil) with an excess of Na azide in boiling alc

*Refs*: 1)Beil **7**, [587] 2)A.Korczyński & St. Namyslowski,BullFr [4] **35**,1190(1924) & CA **19**, 644(1925)

**2,3,5,6-Tetraazido-1,4-benzoquinone,** $O:C_6(N_3)_4:O$; mw 272.16, N 61.76%; brn-yel to blue-black shiny prisms, mp-expl violently on heating and by impact or friction; diffc sol in cold alc; decompd by dissolving in common org solvs or by Na sulfide soln, evolving nitrogen; also dissolves in NaOH, giving a yel-colored soln, and in sulfuric acid giving a grn soln, both evolving nitrogen; was prepd by treating 2-azido-3,5,6-trichloro-1,4-benzoquinone in dil alc at 20° with an excess of Na azide(Ref 3) or by carefully warming 2,5-diazido-3,6-dichloro-1,4-benzoquinone in alc with Na azide(Ref 2)

*Refs*: 1)Beil **7**, [587] 2)K.Fries & P.Ochwat, Ber **56**,1304(1923) & JCS **124** I,844(1923) 3)A. Korczyński & St.Namyslowski,BullFr [4] **35**,1190 (1924) & CA **19**,644(1925)

**3,4,5,6-Tetraazido-1,2-benzoquinone,** $O:C_6(N_3)_4:O$; mw 272.16, N 61.76%; dk-violet crysts, dec on storage; mp expl on heating; sol in glac AcOH, alc or eth, with decmpn; was prepd from tetrabromo-1,2-benzoquinone and an excess of Na azide in glac AcOH. The explosibility of the crysts prevented their analysis

*Refs*: 1)Beil **7**, [567] 2)A.Korczyński & St. Namyslowski,BullFr [4] **35**,1190(1924) & CA **19**, 644(1925)

**Nitro and Other Derivatives of Benzoquinone**

*Mononitro*, $C_6H_3NO_4$, *Dinitro*, $C_6H_2N_2O_6$ and *Trinitro*, $C_6HN_3O_8$ *derivs* were not found in Beil or in CA thru 1956

**3,4,5,6-Tetranitro-1,2-benzoquinone,** $O:C_6(NO_2)_4:O$; mw 288.09, N 19.45%; orn-red or yel ndls (from boiling w); soln in w is yel; was prepd by nitrating 3,4-dihydroxybenzoic acid with nitric acid, alone or in glac AcOH. Oxalic acid was also formed in the reaction. The expl props of

the tetranitro deriv were not detd
*Refs*: 1)Beil **7**,(340) 2)F.von Hemmelmayr, Monatsh **34**,815(1913) & JCS **104** I,728(1913)

**2,3,5,6-Tetra-(2-nitrophenylmercapto)-1,4-benzoquinone**, $(O_2N.C_6H_4.S)_4C_6O_2$; mw 720.74, N 7.78%; brn-yel prisms(from nitrobenz), mp-expl violently when heated; diffc sol in common org solvs; was prepd by treating tetrachloro-1,4-benzoquinone(chloranil) with an excess of 2-nitrothiophenol in alc
*Refs*: 1)Beil **8**, [572] 2)K.Fries & P.Ochwat, Ber **56**,1302(1923) & JCS **124** I,844(1923)

**Substituted Diazonium Derivatives of Benzoquinone**

**4-Acetylimino-1-diazonium-1,4-benzoquinone** [called Acetyl-p-phenylenediazoimide by Morgan & Upton (Ref 2) and Benzochinon-(1.4)-acetimid-diazid or N-Acetyl-4-diazo-anilin in Ger(Ref 1)], $CH_3.CO.N:C_6H_4:N_2+H_2O$; mw 179.18, N 23.45%; yel-wh crysts, very unstable at RT, mp-expl ca 127°; compd exploded violently in contact with CuO and a stream of air; was prepd by treating a well-cooled soln of N-acetyl-p-phenylenediamine in a small amt of acet with liq nitrous anhydride. When an alcoholic soln of N-acetyl-p-phenylenediamine was treated with an ethereal soln of nitrous anhydride and more eth was added, a pale pink crystn ppt separated. It contd 23.18% N and decompd explosively at 95°
*Refs*: 1)Beil **16**,(372) 2)G.T.Morgan & A.W.-Upton,JCS **111**,193-5(1917)

**4-Acetylimino-2-nitro-1-diazonium-1,4-benzoquinone** [called 4-Acetyl-2-nitro-p-phenylene-1-diazo-4-imide by Morgan & Cleage(Ref 2) and 2-Nitro-benzochinon-(1.4)-acetimid(4)-diazid-(1) or N-Acetyl-3-nitro-4-diazo-aniline in Ger(Ref 1)], $CH_3.CO.N:C_6H_3(NO_2):N_2$; mw 206.16, N 27.18%; yel plates, darkens on exposure to light, mp expl ca 142°; was prepd by treating 4-acetyl-2-nitro-p-phenylenediamine(dissolved in dry acet and cooled to -15°) with a 10% acet soln of nitrous anhydride, free from N peroxide
*Refs*: 1)Beil **16**,(373) 2)G.T.Morgan & D.A. Cleage,JCS **113**,591(1918)

**4-Acetylimino-3-nitro-1-diazonium-1,4-benzoquinone**, [called 4-Acetyl-3-nitro-p-phenylene-1-diazo-4-imide by Morgan & Cleage(Ref 2) and 2-Nitro-benzochinon-(1.4)-acetimid-(1)-diazid-(4) or N-Acetyl-2-nitro-4-diazo-anilin in Ger(Ref 1)], $CH_3.CO.N:C_6H_3(NO_2):N_2$; mw 206.16, N 27.18%; brn-red plates, mp expl violently at 140°; was prepd from 4-acetyl-2-nitro-p-phenylenediamine, dissolved in acet, by treatment with acet solns of nitrous anhydride and acetic anhydride. The addn of eth produced a ppt which was stabilized as acetylation proceeded
*Refs*: 1)Beil **16**,(373) 2)G.T.Morgan & D.A. Cleage,JCS **113**,592-3(1918)

**4-Acetylimino-2,6-dichloro-1-diazonium-1,4-benzoquinone**, [called 4-Acetyl-2,6-dichloro-p-phenylene-1-diazo-4-imide by Morgan & Cleage(Ref 2) and 2.6-Dichlor-benzochinon-(1.4)-acetimid-(4)-diazid-(1) or N-Acetyl-3.5-dichlor-4-diazo-anilin in Ger(Ref 1)], $CH_3.CO.N:C_6H_2(Cl)_2:N$; mw 230.05 N 18.26%; almost col plates, mp expl ca 138°; was prepd from 2,6-dichloro-p-phenyldiamine, in water, by acetylation with acetic anhydride and diazotization of the 4-acetylimino deriv, in acet cooled to -15°, with nitrous anhydride in acet; dry eth pptd the product
*Refs*: 1)Beil **16**,(373) 2)G.T.Morgan & D.A. Cleage,JCS **113**,594(1918)

**4-Acetylimino-3,5-dichloro-1-diazonium-1,4-benzoquinone** [called 1-Acetyl-3,5-dichloro-p-phenylene-1-diazo-4-imide by Morgan & Cleage(Ref 2) and 2.6-Dichlor-benzochinon-(1.4)-acetimid-(1)-diazid-(4) or N-Acetyl-2.6-dichlor-4-diazo-anilin in Ger (Ref 1)], $CH_3.CO.N:C_6H_2(Cl)_2:N_2$; mw 230.05, N 18.26%; orn-yel cryst, very rapidly changes to chocolate in the light, mp 133°(dec) [*Form 1*] and dk-gray ppt, darkens on exposure to light, mp expl 138° [*Form 2*]. *Form 1* was prepd by diazotizing 1-acetyl-2,6-dichloro-p-phenylenediamine (same as 4-acetyl-3,5-dichloro-p-phenylenediamine), in dry acet, with nitrous anhydride, dissolved in acet, and pptg the product by adding dry eth. *Form 2* was prepd from 2,6-dichloro-p-phenylenediamine, in dry acet at -10°, by diazotization with nitrous anhydride in acet and acetylation of the product with $Ac_2O$
*Refs*: 1)Beil **16**,(373) 2)G.T.Morgan & D.A. Cleage,JCS **113**,595-6(1918)

**4-Benzoylimino-1-diazonium-1,4-benzoquinone** [called Benzoyl-p-phenylenediazoimide by Morgan & Upton(Ref 2) and Benzochinon-(1.4)-benzimid-diazid or N-Benzoyl-4-diazo-anilin in Ger(Ref 1)] $C_6H_5.CO.N:C_6H_4:N_2$; mw 223.23, N 18.83%; pale yel crysts(from acet+eth), mp expl ca 139°; was prepd by treating N-benzoyl-p-phenylenediamine with a soln of nitrous anhydride in acet, cooled in ice and salt; the product separated on pouring well-cooled eth into the soln
*Refs*: 1)Beil **16**,(372) 2)G.T.Morgan & A.W.

Upton, JCS **111**, 195(1917)

**4-Formylimino-1-diazonium-1,4-benzoquinone** [called Formyl-p-phenylenediazoimide by Morgan & Upton(Ref 2) and Benzochinon-(1.4)-formylimid -diazid or N-Formyl-4-diazo-anilin in Ger(Ref 1)], $OHC.N:C_6H_4:N_2+1.5H_2O$; mw 174.16, N 24.13%; pale yel crysts, very unstable, darkens even in absence of light and evolves $N_2$ at RT; mp expl ca 125-8°; was prepd by adding N-formyl-p-phenylenediamine to a soln of nitrous anhydride in cooled, dry acet; cooled dry eth was added to separate the prod

*Refs*: 1)Beil **16**,(371) 2)G.T.Morgan & A.W.Upton, JCS **111**, 190-3(1917)

**4-Phenylimino-1-diazonium-1,4-benzoquinone** (called p-Chinon-anil-diazid or 4-Diazo-diphenylamin in Ger), $C_6H_5.N:C_6H_4:N_2$; mw 195.22, N 21.53%; brn-yel crysts, mp expl moderately on heating; sl sol in chlf or acet, giving a brn-colored soln; insol in w; was first obtd in an impure state as a brn substance by Ikuta(Ref 2) and prepd in a pure state by Hantzsch(Ref 3) by treating a cooled aq suspension of diphenylamine-4-diazonium sulfate with ammonia. The constitution and structure of this class of compds have been discussed by Morgan & Micklethwait(Ref 4) and by Morgan & Read(Ref 5)

*Refs*: 1)Beil **16**,603 2)M.Ikuta, Ann **203**,282 (1888) 3)A.Hantzsch, Ber **35**,895(1905) 4)G.T. Morgan & M.G.Micklethwait, JCS **93**,605-8(1908) 5)G.T.Morgan & H.N.Read, JCS **121** II,2710-11 (1922)

**4-(2'-Nitrophenylimine)-1-diazonium-1,4-benzoquinone** [called 2-Nitrophenyl-p-phenylenediazoimine by Morgan & Micklethwait(Ref 2) and p -Chinon-(2-nitro-anil)-diazid or 2'-Nitro-4-diazo -diphenylamin in Ger(Ref 1)], $O_2N.C_6H_4.N:C_6H_4:N_2$; mw 240.22, N 23.33%; scarlet amor ppt, darkens at 30°; mp expl at 85-90°; was prepd by diazotizing the hydrochloride of 2-nitrophenyl-p -phenylenediamine and pptg the prod by adding well-cooled ammonia to its Na acetate soln. The dry substance is extremely unstable, dec at RT and expl when gently rubbed on a hard surface

*Refs*: 1)Beil **16**,603 2)G.T.Morgan & M.G.Micklethwait, JCS **93** I,612(1908)

**4-4'-Nitrophenylimine)-1-diazonium-1,4-benzoquinone** [called 4-Nitrophenyl-p-phenylenediazoimide by Morgan & Micklethwait(Ref 2) and p -Chinon-(4-nitro-anil)-diazid or 4'-Nitro-4-diazo -diphenylamin in Ger(Ref 1)], $O_2N.C_6H_4.N:C_6H_4:N_2$; mw 240.22, N 23.33%; red crysts, with a copper luster, mp expl violently at 60-65°; was prepd by diazotizing the hydrochloride of 4-nitrophenyl-p-phenylene-diamine and pptg the product by adding ammonia. The dry subst expl when rubbed

*Refs*: 1)Beil **16**,603 2)G.T.Morgan & M.G. Micklethwait, JCS **93** I,611(1908)

**4-(2',4'-Dinitrophenylimine)-1-diazonium-1,4 -benzoquinone** [called 2,4-Dinitrophenyl-p-phenylenediazoimine by Morgan & Micklethwait(Ref 2) and p-Chinon-(2.4-dinitro-anil)-diazid or 2'.4'-Dinitro-4-diazo-diphenylamin in Ger(Ref 1)], $(O_2N)_2C_6H_3.N:C_6H_4:N_2$; mw 285.22, N 24.56%; red cryst, darken on exposure to light, mp expl on heating ca 110-115°; sl sol in alc; sol in benz with some decompn; was prepd by adding K bicarbonate to an aq soln of 2,4-dinitrophenyl-p-aminobenzenediazonium chloride, previously obtd by diazotizing the hydrochloride of 2,4-dinitrophenyl-p-phenylenediamine

*Refs*: 1)Beil **16**,603 2)G.T.Morgan & M.G.Micklethwait, JCS **93** I,610(1908)

**4-(2',4',6'-Trinitrophenylimino)-1-diazonium-1,4 -benzoquinone** [called 2,4,6-Trinitrophenyl-p -phenylenediazoimine by Morgan & Micklethwait (Ref 2) and p-Chinon-(2.4.6-trinitro-anil-diazid or 2'.4'.6'-Trinitro-4-diazo-diphenylamin in Ger. (Ref 1)], $(O_2N)_3C_6H_2.N:C_6H_4:N_2$; mw 330.22, N 25.45%; brn-red, diamond-shaped crysts(from benz+petr eth), mp expl ca 120-130°; was obtd by filtering a freshly prepd diazotized soln of 2,4,6-trinitrophenyl-p-phenylenediamine(picryl-p -phenylenediamine) into aq Na acetate. On expln, the prod emits clouds of black smoke

*Refs*: 1)Beil **16**,603 2)G.T.Morgan & M.G. Micklethwait, JCS **93** I,609(1908)

**Benzoquinone-1,4-azine** (called p-Chinon-azin in Ger), $O:C_6H_4:N.N:C_6H_4:O$; mw 212.20, N 13.20%; crysts from org solns in two modifns: as dk orn -red prisms or ndls, mp 2-3° and as dk-yel rhombohedral lfts or plates, mp 42°; both modifns have a blue reflex; on heating to higher temps, the color darkens and the crysts expl at ca 185°; readily sol in benz, chlf, hot abs alc, hot et acet, hot acet or hot glac AcOH; diffc sol in eth or in boiling w; almost insol in petr eth; was prepd by shaking an ethereal soln of p-azophenol with silver oxide and fused Na sulfate(Ref 2). Other props and methods of prepn are given in Refs 1 & 3

*Refs*: 1)Beil **7**,628,(345) & [576] 2)R.Willstätter & H.M.Benz,Ber **39**,3486(1906) & JCS **90** I,997(1906) 3)L.Hunter & S.Barnes, JCS **1928**,2055

**Benzoquinonediimine and Derivatives**

**Benzoquinone-1,4-diimine** [called Benzochinon -(1.4)-diimid; p-Chinondiimid or Chinondiimid in Ger], $HN:C_6H_4:NH$; mw 106.12, N 26.40%; lt-yel ndls, becoming brn-yel or gray on standing in air; mp ca 124° (begins to darken at ca 75°); expl when heated rapidly above mp; readily sol in warm et acet; sol in chlf or boiling benz; diffc sol in petr eth; expl when brought into contact with concd hydrochloric or sulfuric acid; was prepd by Willstätter & Mayer (Ref 2) by treating an ethereal suspension of the dichlorohydrate of benzoquinone-1,4-dichloro-imine, $C_6H_4N_2Cl_2.2HCl$, with ammonia gas. Its *Perchlorate salt*, $C_6H_6N_2+2HClO_4$ (?), wh crysts, mp expl violently on heating; in the presence of moisture, color changes to blue-grn, violet and then to brn; was prepd by Hofman et al (Ref 3) by the interaction of benzoquinone-1,4-diimine and perchloric acid

*Refs*: 1)Beil **7**,620,(344) & [574] 2)R.Willstätter & E.Mayer,Ber **37**,1499 & 1501(1904) 3)K.A.Hofmann et al,Ber **43**,180(1910)

**Benzoquinone-1,4-di(bromo-imine)**, $BrN:C_6H_4:NBr$, mw 263.94, N 10.62%; crysts, mp expl ca 86°; was claimed to have been prepd by Krause(Ref 2) by treating an aq soln of p-phenylenediamine chloride with an excess of bromine water. No analysis of the compd was given

*Refs*: 1)Beil- not found 2)A.Krause,Ber **12**,50 (1879)

**Benzoquinone-1,4-di(chloro-imine)** [called Benzochinon-(1.4)-bis-chlorimid or p-Chinon-bis-chlorimid in Ger], $ClN:C_6H_4:NCl$; mw 175.02, N 16.01%; ndls(from w) having a sl aromatic odor, mp 124 -6°(dec); expl when heated rapidly above the mp; readily sol in hot alc, hot AcOH, eth or benz; sl sol in hot w; almost insol in cold w; was first prepd by Krause(Ref 2) by treating an ice-cold soln of p-phenylenediamine in dil HCl with an excess of chlorinated lime(bleaching powder). Other props & methods of prepn are given in Ref 1. It forms addn compds, some of which are expl: *Benzidine Compound*, $C_6H_4N_2Cl_2+2(C_{12}H_{12}N_2)$, violet crysts(from benz), mp expl mildly at ca 121°(Ref 3); *Hydroquinone Compound*, $C_6H_4N_2Cl_2+C_6H_6O_2$, dk-grn ndls, mp expl ca 129-130°, dec on warming with w or benz(Ref 3)

*Refs*: 1)Beil **7**,621,(344) & [574] 2)A.Krause, Ber **12**,47(1879) 3)A.Knorr, Ber **43**,799(1910)

**Benzoquinone-1,4-di(methylimine)**, $CH_3N:C_6H_4:N.CH_3$; mw 134.18, N 20.88%; wh crysts, mp ca 92.5-93°, giving a red liq; readily sol in chlf, eth or benz(giving a yel soln); sol in excess w or alc; rapidly decomps in solns, separating a dk product; expl on contact with HCl or $H_2SO_4$; was prepd by heating a soln of sym-dimethyl-p-phenylenediamine in gasoline with lead peroxide(Refs 1 & 2)

*Refs*: 1)Beil **7**,621 2)R.Willstätter & A.Pfannenstiel,Ber **38**,2249(1905)

*Benzoquinone-1-imino-4-methylimine*, $CH_3.N:C_6H_4:NH$; mw 120.15, N 23.32%; col prisms, mp 64 -7°, very unstable compd, dec on standing in less than 1 hr, becoming a brn tarry product. Other props & prepn are given in Refs 1 & 2

*Refs*: 1)Beil **7**,620 2)R.Willstätter & C.W.Moore, Ber **40**,2671(1907)

*Benzoquinone-1-imino-4-dimethylammonium hydroxide* [called Benzochinon-(1.4)-imid-dimethylimmoniumhydroxyd in Ger], $HO-(CH_3)_2N:C_6H_4:NH$; mw 152.19, N 18.41%. Obtd as the *Dinitrate salt*, $O_3N.(CH_3)_2N:C_6H_4:NH.HNO_3$, yel prisms, dec on storage, mp expl on heating; sol in w, giving a dk-red soln; was prepd by passing N oxides into an alc soln of asym-dimethyl-p-phenylenediamine and nitric acid

*Refs*: 1)Beil **7**,621 2)R.Willstätter & J.Piccard, Ber **41**,1473(1908) & JCS **94** I,476(1908)

**2,3,5-Trinitrobenzoquinone-1-imino-4(?)-trimethylimine** [called 2,3,5-Trinitro-benzochinon-(1.4) -imid-(1)-trimethylimid-(4)(?) in Ger], $(CH_3)_3N:C_6H_4(NO_2)_3:NH(?)$; mw 285.22, N 24.56%; golden -yel scales, mp dec at 200-220°; insol in w or alc; soln in HCl is colorless; dec on heating the acid soln near boiling; was prepd from trimethyl-(4--acetylaminophenyl)-ammonium nitrate by nitration with fuming nitric and concd sulfuric acids. The prod is unstable

*Refs*: 1)Beil **7**,(350) 2)R.Meldola & W.R.Hollely, JCS **107** I,621(1915)

**Benzoquinonedioxime and Derivatives**

*Benzoquinone-1,4-dioxime* [called Benzochinon -(1.4)-dioxim or p-Chinondioxim in Ger], $HO.N:C_6H_4:N.OH$; mw 138.12, N 20.28%; lt gray granular crysts(from boiling w) or lt yel ndls(hydrate), mp 240°(dec); sol in concd $NH_4OH$; sl sol in w; v sl sol in dil aq $NH_4OH$; was first prepd by

Nietzki & Kehrmann(Ref 2) by various methods. Other props and methods of prepn are given in Ref 1. Benzoquinone-1,4-dioxime forms interesting derivs, some of which are expl(see below). Jerczak & Fettes(Ref 3) proposed its use in the "vulcanization" or "curing" of rubber-like polymeric substs

*Refs:* 1)Beil **7**,627 & [576] 2)R.Nietzki & F. Kehrmann,Ber **20**,614(1887) 3)J.S.Jerczak & E. M.Fettes,IEC **43**,326(1951)

**Benzoquinone-1,4-dioxime,Oxidation Product**[called "p-Dinitrosobenzal" by Nietzki & Kehrmann (Ref 2) and called "p-Benzoquinonedioxime Peroxide" by Forster & Barker(Ref 3)],$\overline{O.N:C_6H_4:N.O}$; mw 136.11, N 20.58%; golden-yel ppt, mp dec with mild expln when heated rapidly; very sl sol in common org solvs; was prepd by the oxidn of benzoquinone-1,4-dioxime in alk soln with K ferricyanide(Ref 2) and by the action of hydrazine hydrate in boiling alc soln on p-phenylenediamine (Ref 3)

*Refs:* 1)Beil **7**,628 & (345) 2)R.Nietzki & F. Kehrmann,Ber**20**,615(1887) & JCS **52** I,575(1887) 3)M.O.Forster & M.F.Barker,JCS **103** II,1922(1913)

**Benzoquinone-1,4-dioxime Polymers of the Anhydride**[called Polymeres-p-Chinon-dioximanhydrid in Ger], $\left[\begin{matrix}-O-\\(N:C_6H_4:N)_x\end{matrix}\right]$; mw $(120.11)_x$, N $(23.33)_x$%; lt-red amor subst, mp expl violently when heated above 300°; insol in all known solvs; was obtd by allowing the aq soln of the Na salt to stand. The prod is very unstable in storage

*Refs:* 1)Beil **7**,628 2)R.C.Farmer & A.Hantzsch, Ber **32**,3107(1899) & JCS **78** I,103(1900)

### Benzoquinoneimine and Derivatives

*Benzoquinone-1,4-monoimine*[called Benzochinon-(1.4)-monoimid; p-Chinon-monoimid or p-Chinonimid in Ger], $HN:C_6H_4:O$; mw 107.11, N 13.08%; lt sulfur-yel crysts, mp expl mildly on heating; unstable in the dry state; readily sol in eth or benz; mod sol in $CS_2$; other props & prepn are given in Refs

*Refs:* 1)Beil **7**,619 & [574] 2)R.Willstätter & A. Pfannenstiel,Ber **37**,4607(1904) 3)F.Kehrmann, Ber **56**,2399(1923)

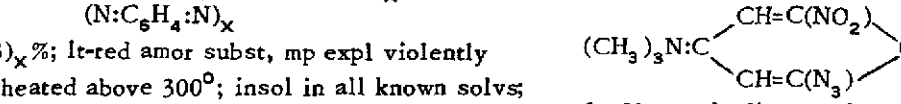
**Benzoquinone-1,4-monochloroimine** [called Benzochinon-(1.4)-mono-chlorimid; p-Chinon-monochlorimid or Chinonchlorimid in Ger], $Cl.N:C_6H_4:O$; mw 141.52, N 9.90%; yel ndls(from gasoline or glac AcOH), mp 85°(partially sublimes), expl at higher temps; very sol in eth, chlf or hot alc; insol in w or dil acids; dissolves w/o decompn in cold concd $H_2SO_4$ or fuming $HNO_3$. Other props & methods of prepn are given in Ref 1. Its addn compd with hydroquinone, $C_6H_4NOCl+C_6H_6O_2$, bl-grn crysts with a metallic luster, mp expl at ca 119°, dec on heating with w or benz, was prepd by Knorr(Ref 2)

*Refs:* 1)Beil **7**,619,(344) & [574] 2)A.Knorr,Ber **43**,799(1910)

**Benzoquinone-1,4-monocyanhydrin**[called p-Chinon-mono-cyanhydrazon, Benzochinon-(1.4)-mono-cyanhydrazon or p-Oxy-benzolazoformonitril in Ger], $NC.HN.N:C_6H_4:O$; mw 147.13, N 28.56%; yel ndls(from alc+w), mp expl ca 117-118°; readily sol in eth or alc; was prepd from p-hydroxybenzenediazonium chloride and concd KCN soln, dissolving the resulting compd in w and pptg the product with HCl

*Refs:* 1)Beil **7**,629 & [577] 2)A.R.Hantzsch & W. B.Davidson,Ber **29**,1532(1896) & JCS **70** I,541 (1896)

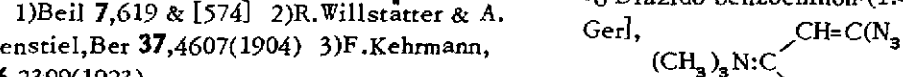
**2-Azido-6-nitro-4-trimethylammonium-1,4-benzoquinone**[called 2-Nitro-6-triazo-4-trimethylammonium-1-benzoquinone by Meldola & Hollely (Ref 2) and called 6-Nitro-2-azido-benzochinon-(1.4)-trimethylimid-(4) in Ger],



$$(CH_3)_3N:C\begin{matrix}\diagup CH=C(NO_2)\diagdown\\ \diagdown CH=C(N_3)\diagup\end{matrix}C:O$$; mw 237.22, N 29.53%; red ndls or red scales(from w), mp- becomes dk-brn at 100° and expl; was prepd from 2,6-dinitro-4-trimethylammonium-1-benzoquinone by reducing it with ammonium sulfide, converting the nitro-amino compd into a chloride, diazotizing the product and treating it with Na azide. This compd is distinctly basic and its salts with mineral acids are colorless

*Refs:* 1)Beil **13**,(198) 2)R.Meldola & W.F.Hollely, JCS **105** I,1477(1914)

**2,6-Diazido-4-trimethylammonium-1,4-benzoquinone** [called 2,6-Bistriazo-4-trimethylammonium-1-benzoquinone by Meldola & Hollely(Ref 2) and called 2-6-Diazido-benzochinon-(1.4)-trimethylimid-(4) in Ger],

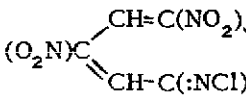


$$(CH_3)_3N:C\begin{matrix}\diagup CH=C(N_3)\diagdown\\ \diagdown CH=C(N_3)\diagup\end{matrix}C:O$$; mw 233.23, N 42.04%; brn subst, mp expl ca 100°; very sol in w; decomp in boiling w; was prepd by reducing the dinitro-compd with tin and HCl, diazotizing the product and treating it with Na azide. The compd was not obtd in a pure state but its salts

were sufficiently definite to establish its constitution. *Chloride salt*, $C_9H_{11}N_7O$+HCl, col ndls, becoming brn on exposure to air, mp expl ca 100°; dec in w or alc; *Picrate salt*, $C_9H_{21}N_7O+C_6H_3N_3O_7$, yel scales(from alc), mp very expl compd, its melting or decompg point could not be detd

*Refs*: 1)Beil **13**,(198) 2)R.Meldola & W.F.Hollely,JCS **105** I,1478-80(1914)

**4,6-Dinitro-1,2-benzoquinone-2-chlorimine** [called 3,5-Dinitro-benzochinon-(1.2)-chlorimid-(1) in Ger]



$(O_2N)C$, $CH=C(NO_2)$, $C:O$, $CH-C(:NCl)$; mw 231.56, N 18.14%; yel pdr, mp expl; readily sol in acet; sol in methanol, alc or glac AcOH; sl sol in benz, eth or xylol; diffc sol in cold w; partially decompg in boiling w; was obtd, in an impure state, by treating a soln of picramic acid, in the presence of HCl, with cold chlorine water, The expl props of this compd were not investigated

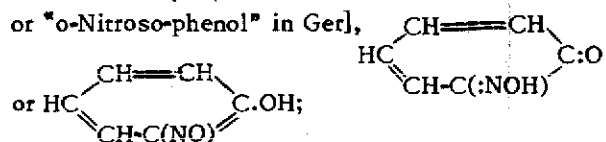
*Refs*: 1)Beil **7**,[567] 2)S.Blaszkovska,BullInterAcadPolonaise **9-10A**,409(1924);JCS **128** II,1043 (1925) & CA **20**,1552(1926)

**Benzoquinone-1-imino-4-diazonium Salts.** The expl salts *Hydrochloride, Chromate, and Picrate* are described in Vol 1 of this Encyclopedia under **1-Aminobenzene-4-diazonium Hydroxide or Anilino-4-diazonium Hydroxide.** These salts were originally considered to be derivs of the hypothetical hydroxide, $H_2N.C_6H_4.N(:N).OH$, as parent compd (Refs 1 & 2). Gray(Ref 3) claims that these salts possess a quinoid structure and are not derivs of aminobenzene diazonium hydroxide but salts of 1-imino-4-diazido-benzoquinone

*Refs*: 1)Beil **16**,602 & [306] 2)R.Meldola & L. Eynon,JCS **87** I,2(1905) 3)W.H.Gray,JCS **1926**, 3174-3179

## Benzoquinonemonoöxime and Derivatives

**Benzoquinonemonoöxime**, $C_6H_5NO_2$; mw 123.11, N 11.38%. This compd exists as ortho and para isomers: *Benzoquinone-1,2-monoöxime* [called Benzochinon-(1.2)-monoxim; o-Chinon-monoxim or "o-Nitroso-phenol" in Ger],

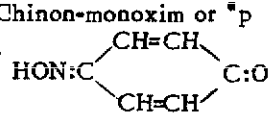


or HC, CH=CH, C.OH; CH-C(NO); HC, CH=CH, C:O; CH-C(:NOH)

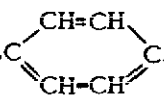
dk grn-yel ndls(from petr eth), mp 142°(dec); other props and methods of prepn are given in Ref 1. It forms numerous salts, some of which are expl:

*Silver salt*, $AgC_6H_4NO_2$, almost black, but dk blue in transmitted light, fine crysts, expl on heating or on contact with acids; *Sodium salt*,, $NaC_6H_4NO_2$, red-grn shiny lfts, expl on heating

*Benzoquinone-1,4-monoöxime* [called Benzochinon-(1.4)-monoxim; p-Chinon-monoxim or "p-Nitroso-phenol" in Ger],



HON:C, CH=CH, C:O, CH=CH



or ON.C, CH=CH, C.OH, CH=CH; almost col ndls(by rapid cooling from boiling w) or yel-wh ndls(from acet+benz), mp 133°(dec); other props and methods of prepn are given in Ref 2. It forms numerous salts, some of which undoubtedly are expl

*Refs*: 1)Beil **7**,600,(337) & [566] 2)Beil **7**,622, (344) & [574]

**Benzoquinone-1-(β-chloroethylimine)-4-oxime** [called p-Chinon-(β-chlor-äthylimid)-oxim in Ger], $HO.N:C_6H_4:N.CH_2-CH_2.Cl$; mw 184.63, N 15.18%; dk-grn, steel-blue, iridescent scales(from benz+ligroin), mp ca 90°, dec with expln ca 120°; obtd by reacting aq Na nitrite with (β-chloroethyl)-aniline and treating the nitroso-deriv with alc HCl

*Refs*: 1)Beil **7**,[576] 2)G.R.Clemo & W.H.Perkin, Jr,JCS **125** II,1810(1924)

**Benzoquinone-1,4-monoöxime Hypochlorite**, $ClO.N:C_6H_4:O$; mw 157.56, N 8.93%; yel ndls, very unstable, evolving HOCl when exposed to light: mp expl on heating to ca 70° or on contact with concd $H_2SO_4$; readily sol in alc, eth, chlf or benz; insol in w; was prepd by treating an aq soln of benzoquinone-1,4-monoöxime with HCl and bleaching pdr until a distinct odor of hypochlorous acid,HOCl was observed

*Refs*: 1)Beil **7**,625 2)R.Möhlau,Ber **19**,281(1886) & JCS **50** I,453(1886)

**Benzoquinone-1-semicarbazone-4-oxime**, $HO.N:C_6H_4:N.NH.CO.NH_2$; mw 180.17, N 31.10%; brn-yel ndls(from AcOH & w), mp dec ca 238°, expl ca 247°; sol in glac AcOH; insol in w, alc or eth; was prepd from benzoquinone-1,4-monoöxime and the hydrochloride of semicarbazide in alc soln

*Refs*: 1)Beil **7**,630 2)J.Thiele & W.Barlow,Ann **302**,331(1898) 3)W.Borsche & A.Reclaire,Ber **40**, 3806(1907)

**3-Bromo-1,4-benzoquinone-1-methylimine-4-oxime**,

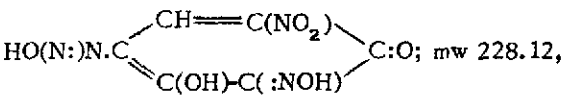
$HO.N:C_6H_3(Br):N.CH_3$; mw 251.07, N 13.03%; grn crysts, mp darkens ca 100° and expl ca 124°; was obtd by hydrolysis of the hydrochloride of methyl (3-bromophenyl)-nitrosoamine. The HCl salt changed from pink to yel at 140° and melted ca 168°

*Refs*: 1)Beil **7**,[583] 2)M.S.Kharasch & J.F. Piccard,JACS **42**,1859(1920)

**2,6-Dibromo-1,4-benzoquinone-4-oxime,** $HO.N:C_6H_2(Br)_2:O$; mw 280.92, N 4.99%; brn ndls(from toluene, alc or AcOH) or lfts(from dil alc); mp darkens ca 160° and detonates betw 168 & 175°; readily sol in alc or eth; sol in chlf or glac AcOH; sl sol in w; other props and methods of prepn are given in Ref 1

*Refs*: 1)Beil **7**,641 2)F.Kehrmann,Ber **21**,3318 (1888)

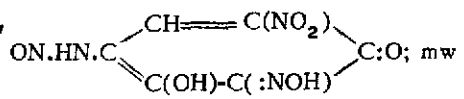
**6-Nitro-3-hydroxy-1,2-benzoquinone-2-oxime-4-diazoniumhydroxide,**



N 24.56%; its chloride and some other derivs were prepd by Heller & Sourlis(Ref 2) who did not investigate their expl properties

*Refs*: 1)Beil **16**,(367) 2)G.Heller & A.Sourlis,Ber **43**,2586-7(1910)

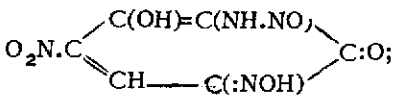
**6-Nitro-4-nitrosoamino-3-hydroxy-1,2-benzoquinone-2-oxime,**



228.12, N 24.56%; dk-yel plates(from acet+w) or crysts(from w), mp expl violently on heating; readily sol in glac AcOH; mod sol in alc; sl sol in benz, chlf or ligroin; was prepd from aq 6-nitro-4-aminoresorcinol hydrochloride or hydrobromide and 2 mols of Na nitrite in acid soln at 0°. Its Na & K acetate solns have a dark-grn color; the crysts of these salts sometimes expl by only rubbing with a glass rod under water

*Refs*: 1)Beil **14**,(494) 2)G.Heller & A.Sourlis, Ber **43**,2585(1910) & JCS **98 I**,749(1910)

**4-Nitro-6-nitrosoamino-5-hydroxy-1,2-benzoquinone-2-oxime,**



mw 228.12, N 24.56%; small yel hex rods(from acet+petr eth), mp expl on heating; readily sol in alc or acet; diffc sol in benz, chlf or petr eth; dec by boiling in water; was prepd from aq 4-nitro-2-aminoresorcinol and 2 mols of $NaNO_2$ in $H_2SO_4$ soln

*Refs*: 1)Beil **14**, [153] 2)G.Heller et al,Ber **56**, 1870(1923)& JCS **124** I,1095(1923)

**Benzotetrazolecarboxylic Acid.** A misnomer for 1,2,3-Triazapyrrocoline-6-carboxylic Acid

### Benzotoluide and Derivatives

*Benzotoluide or Benzomethylanilide* (called Benzoesäuretoluidid, in Ger), $C_6H_5.CO.NH.C_6H_4.CH_3$. Three isomers are described in Beil **12**,795,861, 926,(380,400,421) & [505]. The para isomer is probably of most interest since its tetranitro deriv has been prepd

*Mono-, Di- and Trinitrobenzotoluides*. Several isomers are described in Beil **12** and in Rec **55**, 253-6(1936). None of these is expl

**Tetranitrobenzotoluide**, $C_{14}H_9N_5O_9$ mw 391.25, N 17.90%. One isomer, *3,5-Dinitrobenz-2',6'-dinitromethylanilide*, $(O_2N)_2C_6H_3.CO.NH.C_6H_2(NO_2)_2.CH_3$; pale yel ndls(from AcOH), mp 275°, was prepd by nitration of 3,5-dinitrobenz-4'-methylanilide with abs nitric acid. Its expl props were not investigated

*Refs*: 1)Beil- not found 2)W.B.van Horssen,Rec **55**,255-6(1936) & CA **30**,5199(1936)

### Benzotriazine and Derivatives

**Benzotriazine**, $C_7H_5N_3$; mw 131.13, N 32.05%. The *1,2,3(or vic)-isomer*, HC=CH–C=N–N; HC=CH–C=CH–N seems to exist in the form of derivs, while the *1,2,4(or as)-isomer*, HC=CH–C=N–N, HC=CH–C=N–CH exists as a yel solid, mp 74-5°. Other props & prepn are given in Beil **26**, 67,(15) & [33]

**(Benzo-1,2,3-triazine)-3-oxide or Benzo-3-oxy-vic-triazine**, $C_7H_5N_3O$; yel ndls, mp 160-160.5°(dec). Its 6,8-dibromo-deriv, called "Dibromindiazonoxim" by Bamberger, yel ndls(from benz) expl ca 182°. It was prepd by treating 2-amino-3,5-dibromobenzaldoxime with $NaNO_2$ in AcOH soln

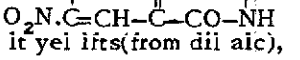
*Refs*: 1)Beil **26**,67 2)E.Bamberger & E.Demuth, Ber **34**,1327-8(1901)

**(Benzo-1,2,3-triazine)-4-oxide or Benzo-4-oxy-vic-triazine** (called 4-Oxy-benzo-1.2.3-triazin in Ger; former name "Benzazimid"), HC=CH–C–N=N; HC=CH–C–CO–NH mw 147.13, N 28.56%. Its other form, HC=CH–C–N=N; HC=CH–C–C(OH)=N which may be called *Benzo-4-hydroxy-vic-triazine*, was prepd by several in-

vestigators using different methods, as crysts decompg ca 211-13° and explg when heated in a flame

It forms salts, some of which are expl, such as *Silver salt*, $AgC_7H_4N_3O$, wh amorph ppt, explg on heating. *Sodium salt*, lt yel lfts, explg on heating or on contact with concd $H_2SO_4$

*Refs*: 1)Beil **26**,163-4 & [88] 2)A.Weddige & H. Finger,JPraktChem **35**,262-4(1887) 3)H.Finger, Ibid **37**,432-4(1888) 4)E.Zacharias,Ibid **43**,446 (1891) 5)A.Reissert & F.Grube,Ber **42**,3721(1909) 6)G.Heller & A.Siller,JPraktChem **116**, 9 & 14 (1927)

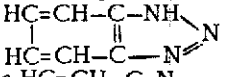
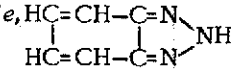
**6-Nitrobenzo-4-oxy-vic-triazine** (called m-Nitrobenzazimid by Kratz),  ; mw 192.13, N 29.16%; lt yel lfts(from dil alc), dec 185° and expl when heated on Pt foil in a flame. Was prepd by treating 5-nitro-2-amino-benzamide with K nitrite in dil AcOH under cooling

Forms salts, some of them expl, such as *Sodium salt*, $NaC_7H_3N_4O_3$, lt yel ndls(from alc+eth), expl on heating

*Refs*: 1)Beil **26**,166 2)K.Kratz,JPraktChem **53**, 213(1896)

**1,2,3-Benzotriazino-[3,4-a] perimidine.** See o-Amidophenylperimidine,Vol 1,p A 246-L

### Benzotriazole and Derivatives

**Benzotriazole** (formerly called *Aziminobenzol* and *Phentriazol* in Ger), $C_6H_5N_3$; mw 119.12, N35.28%; col ndls, mp 95-100°. Two forms are possible: *Benzo-α-ν(or 1,2,3)-triazole*,  and *Benzo-β-ν(2,3,1)-triazole*, 

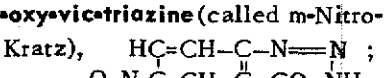
(Ref 1).Many methods of prepn are known, of which the treatment of p-phenylenediamine with Na nitrite in dil AcOH is described in detail in Ref 6. It is not recommended to prep large batches because of the possibility of accidental expln during vacuum distn of benzotriazole. One such expln took place in 1956 at the Maumee Chemical Plant, Toledo, Ohio(Ref 8)

Nitration of benzotriazole is described in Ref 5 and its toxicity and hazard in Ref 9

*Refs*: 1)Beil **26**,38 & [17] 2)A.Ladenburg,Ber **9**, 222(1875) 3)T.Zincke et al,Ann **291**,320(1896) 4)K.Elbs,JPraktChem **108**,213(1924) 5)K.Fries et al,Ann **511**,229(1934) 6)OrgSynth **20**,16(1940) 7)N.L.Miller & E.C.Wagner,JACS **76**, 1850-1(1954) & CA **49**,8264(1955) 8)Anon,C&EN **34**,2450(1956) & CA **50**,12481(1956) 9)Sax(1957),p 350

**Mononitrobenzotriazole**, $C_6H_4N_4O_2$; mw 164.12, N 34.14%. The following isomers are described in the literature: *5(or 6)-Nitrobenzotriazole*, ndls, mp 209-11° (Ref 1), mp 215-6°(Ref 3), its *Silver salt* is a mild expl(Ref 1); *4(or7)-Nitrobenzotriazole*, crysts, dec ca 230°(Ref 2), mp 236-237.3° (Ref 3)

*Refs*: 1)Beil **26**,43 2)Beil **26**,(10) 3)N.L.Miller & E.C.Wagner,JACS **76**,1850-1(1954)

**Dinitrobenzotriazole** $C_6H_3N_5O_4$; mw 209.12, N 33.49%. The following isomer is described in the literature: *2,4-Dinitrobenzo-a-vic-triazole*,  ; col ndls(from dil alc), mp 198°. Can be prepd by treating 3,5-dinitro-phenylenediamine with Na nitrite in aq acid. Its expl props were not investigated

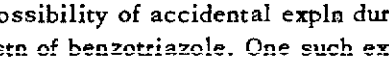
*Refs*: 1)Beil **26**,50 2)R.Nietzki & H.Hagenbach, Ber **30**,543(1897)

*Trinitrobenzotriazole*, $C_6H_2N_6O_6$- not found in Beil or in CA through 1956

### Benzotriazolol and Derivatives

*Benzotriazolol, Hydroxybenzotriazole, Benzohydroxytriazole or Benzazimidol* (Called Oxybenztriazol in Ger), $C_6H_5N_3O$; mw 135.12, N 13.10%. The following isomer is described in the literature: *Benzotriazol-1-ol or (Benzo-1-hydroxy)-a-vic-triazole* (called 1-Oxy-benztriazol; Benzazimidol or Benzolazimidol in Ger), ; ndls, mp 157°. Other props & prepn are given in the Refs. Its *Lead salt*, $Pb(C_6H_4N_3O)_2$, lfts, expl ca 270°

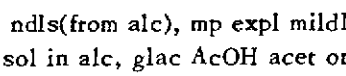
*Refs*: 1)Beil **26**,41 2)R.Nietzki & E.Braunschweig,Ber **27**,3381-w(1894) 3)T.Zincke & P. Schwarz,Ann **311**,332(1900)

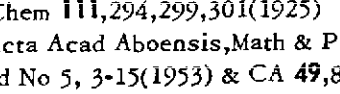
*Benzotriazol-4-ol or (Benzo-4-hydroxy)-a-vic-triazole*,  ; which may be considered as a parent compd of 6-mononitro-benzo-triazol-4-ol described below, could not be found in Beil

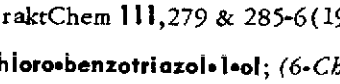
**5-Monochloro-benzotriazol-1-ol**; *(5-Chlorobenzo-1-hydroxy)-a-vic-triazole or 5-Chloro-benzazimidol*, $C_6H_4N_3OCl$; lfts(from dil alc), deflgr at 204-5°. Can be prepd by heating 2,4-dichloro-1-nitrobenzene with an excess of hydrazine-hydrate in alc. Its *Potassium salt*, $KC_6H_3N_3OCl$,

lfts(from alc), deflgr above 300°
*Refs*: 1)Beil **26**,[24-5] 2)E.Müller & G.Zimmermann,JPraktChem **111**,279 & 285-6(1925)

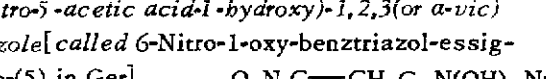
**6-Monochloro-benzotriazol-1-ol**; *(6-Chlorobenzo-1-hydroxy)-α-vic-triazole*, or *6-Chloro-benzazimidole*; col ndls(from dil alc), mp dec ca 195° and expl when heated at higher temp; can be prepd by treating 2,5-dichloro-1-nitrobenzene with an excess of hydrazinehydrate in alc. Its *Silver salt*, $AgC_6H_3N_3OCl$, expl when heated on a Pt foil in a flame
*Refs*: 1)Beil **26**,[25] 2)J.Booy & J.W.Dienske, Rec **45**,449(1926)

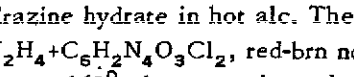
**5,6-Dichloro-benzotriazol-1-ol**; *5,6-Dichlorobenzazimidol or 1-hydroxy-5,6-dichloro-α(or 1H)-benzotriazole*,  , mw 204.02, N 20.60%; ndls(from alc), mp expl mildly ca 194-6°; readily sol in alc, glac AcOH acet or nitrobenz; nearly insol in eth, benz or ligroin. It can be prepd by treating 2,4,5-trichloro-1-nitrobenzene or 4,5-dichloro-2-nitro-phenylhydrazine with hydrazine hydrate in alc soln. The *Hydrazine salt*, $C_6H_3N_3OCl_2+N_2H_4$, ndls(from alc), mp 205°(dec); *Potassium salt*, $KC_6H_2N_3O$, lfts(from alc), mp expl betw 230° and 250°; *Silver salt*, $AgC_6H_2N_3OCl_2$, ppt, sensitive to light; mp expl on heating; *Barium salt*, $BaC_6HN_3OCl_2$, ndls(from w), mp expl mildly on heating or on contact with $H_2SO_4$; *Aniline salt*, $C_6H_3N_3OCl_2+C_6H_7N$, ndls(from methanol), mp 168°(dec) and other salts are described in the literature
*Refs*: 1)Beil **26**, [25] 2)E.Müller & W.Hoffmann, JPraktChem **111**,294,299,301(1925) 3)Compare, W. Qvist,Acta Acad Aboensis,Math & Phys **19**, No 4, 3-11 and No 5, 3-15(1953) & CA **49**,8993-4(1955)

**(5,7-Dichlorobenzo-6-nitro)-benzotriazol-1-ol**; *5,7-Dichloro-6-nitrobenzazimidol or 1-Hydroxy-5,7-dichloro-6-nitro-α(or 1H)-benzotriazole*,  , mw 249.03, N 22.50%; yel ndls(from alc), mp dec ca 196°; readily sol in alc with partial decn. It can be prepd by treating 2,4,6-trichloro-1,3-dinitrobenzene with an excess of hydrazine hydrate in hot alc. The *Hydrazine salt*, $N_2H_4+C_6H_2N_4O_3Cl_2$, red-brn ndls(from alc), mp dec ca 169°; dec on prolonged standing in hot w
*Refs*: 1)Beil **26**, [27] 2)W.Borsche & W.Trautner, Ann **447**,6(1926) 3)Compare, S.S.Joshi & D.S. Deorha,JIndianChemSoc **29**,548(1952) & CA **47**, 8738-9(1953)

**4-Mononitro-benztriazol-1-ol**; *4-Nitrobenzo-1-hydroxy-α-vic-triazole or 4-Nitrobenzazimidol*,  ; mw 180.12, N 31.11%; orn crysts of the monohydrate lose w ca 140° and deflgr ca 229° with evoln of flame and smoke; easily sol in dil alc; diffc sol in w. Can be prepd by treating 2,6-dinitrophenylhydrazone with cold NaOH soln or warm ammonia
*Refs*: 1)Beil **26**,(11) 2)W.Borsche & D.Rantscheff, Ann **379**,172(1911)

**6-Mononitro-benzotriazol-1-ol**; *(6-Nitrobenzo-1-hydroxy)-α-vic-triazole or 6-Nitro-benzazimidol*, mw 180.12, N 31.11%, yel crysts, mp deflgr 190-2° (Ref 2), dec explosively 206°(Refs 3 & 4); sol in hot w, hot alc or hot NB; insol in eth, ligroin or benz. Can be prepd by heating 4-chloro-1,3-dinitrobenzene with hydrazine hydrate in alc(Ref 4) or by other methods(Refs 1,2 & 3). Forms many salts, some of them expl, such as: *Potassium salt*, $KC_6H_3N_4O_3$, orn-yel crysts, dec explosively on heating; *Sodium salt*, $NaC_6H_3N_4O_3$, red ndls, dec expl on heating(Ref 2); *Hydrazine salt*, $C_6H_4N_4O_3.N_2H_4$, yel ndls(from alc), dec at 205-6°
*Refs*: 1)Beil **26**,48 & [26] 2)T.Curtius,JPraktChem **76**, 374 & 383-5(1907) 3)L.Spiegel,Ber **41**,886(1908) 4)O.L.Brady & J.N.E.Day,JCS **123**,2226(1923) 5)M.Tomita & K.Ikawa,JPharmSocJapan, **75**,457(1955) & CA **50**,2480(1956) Chem **76**,374 & 383-5(1907) 3)M.Tomita & K. Ikawa,JPharmSocJapan, **75**,457(1955) & CA **50**, 2480(1956)

**(6-Mononitro-5-acetic acid)-benzotriazol-1-ol** or *(6-Nitro-5-acetic acid-1-hydroxy)-1,2,3(or α-vic)-triazole*[*called* 6-Nitro-1-oxy-benztriazol-essigsäure-(5) in Ger],  ; mw 238.16, N 23.53%; yel lfts(from w), mp darkens above 200°, expl ca 224°; was prepd by reacting 4,6-dinitro-3-hydrazino-phenylacetate with dil NaOH soln
*Refs*: 1)Beil **26**,[158] 2)W.Borsche,Ber **54**,678 (1921) & JCS **120** I,462(1921)

**6-Mononitro-benzotriazol-4-ol**; *(6-Nitrobenzo-4-hydroxy)-α-vic-triazole or 6-Nitro-benzotriazol-4-ol*,  ; mw 180.12, N 31.11% yel pdr, mp 197-8°; was prepd by refluxing for 6 hrs 4-methoxy-6-nitrobenzotriazole with 48% HBr soln. Its expl props were not investigated

*Refs*: 1)Beil-not found 2)H.B.Gillespie et al, JACS **76**,3532(1954) & CA **49**,9633(1955)
*Note:* No higher nitrated derivs of Benzotriazolols were found in Beil or in CA thru 1956

**Benzotrifluoride and Derivatives**

*Benzotrifluoride or Phenylfluoroform* (called 1'.-1'.1'-Trifluor-1-methyl-benzol and ω.ω.ω-Trifluor-toluol in Ger), $C_6H_5.CF_3$; col liq, bp 103.1 at 752mm. Other props & prepn are given in Beil **5**, 290(149) & [224] and its toxicity and hazard in Sax(1957),351

*Mononitrobenzotrifluoride*, $O_2N.C_6H_4.CF_3$. The following isomers are described in the literature: *2-Nitro-*, crysts(from alc), mp 32.5°(Ref 2) *3-Nitro-*, col liq, fr p -2.4°, bp 102-3° at 40mm; d 1.4318 at 18/4°, $n_D$ 1.47418 at 18/4°, $Q_C^v$ 771.3kcal/mol; can be prepd by treating benzotrifluoride with fuming nitric acid(Ref 1) and *4-Nitro-*, crysts, mp 41.5°(Ref 2)
*Refs*: 1)Beil **5**,327,(162) & [251] 2)Beil **5**,[251]

**Dinitrobenzotrifluoride**, $(O_2N)_2C_6H_3.CF_3$; mw 236.11 N 11.86%. The *3,5-Dinitro-isomer* is described in the literature. It consists of wh crysts, melting at 49-50°; can be prepd by treating 3-nitrobenzotrifluoride with a mixt of fuming nitric acid(d 1.49-1.50) and oleum(20% free $SO_3$) at 95-100°. Its expl props were investigated ca 1950 at PicArsn and at the National Northern Corp, but their results are classified
*Refs*: 1)Beil- not found 2)E.C.Finger et al, TransIllinoisStateAcadSci **31**,132(1939) & CA **33**, 6271(1939) 3)E.C.Finger & F.H.Reed,JACS **66**, 1973-4 (1944)

**1,2,3-Benzoxadiazole.** See Benzenediazooxide

**2,1,3-Benzoxadiazole.** See Benzofurazan

**Benzoylacetateperoxide.** See Acetylbenzoylperoxide; Vol 1,p A55-L

**Benzoylacetylperoxide.** See Acetylbenzoylperoxide; Vol 1,p A54-R

**Benzoyl Amide.** See Benzamide

**Benzoylaminoglyoxime or Aminobenzoylglyoxime**, $C_6H_5.CO.C(:N.OH).C(:N.OH).NH_2$; mw 171.16, N 24.55%. Two isomers are described in the literature, the *α*-isomer, mp 127°(dec) and the *β*-isomer, mp 187°(dec). The *Silver salt* of the *α*-isomer, $AgC_9H_8N_3O_3$, yel ppt, expl at ca 130°, while its *peroxide*, $C_6H_5.CO(C_2N_2O_2).NH_2$, golden-yel solid, dec ca 145°

*Refs* 1)Beil **10**,[566] 2)G.Ponzio & C.Cerrina, *Gazz* **58**,29-31(1928) & CA **22**,1971(1928)

**Benzoylaminophenol.** See Benzamidophenol

**Benzoylaniline.** See Benzanilide

**Benzoylazide and Its Nitro Derivatives.** See under Benzoic Acid

**Benzoylazide Benzalhydrazone.** See under Benzoic Acid

**Benzoyl Azidodithiocarbonate.** See Vol 1,p A633-L

**Benzoylazidomethane.** See Acetophenone, Azido Derivatives; Vol 1,p A47-R

**Benzoylchloride and Derivatives**

*Benzoylchloride or Benzoic Acid Chloride* (called Benzoesäurechlorid in Ger), $C_6H_5.COCl$; mw 140.57 col, pungent liq, d 1.212 at 20/4°, mp -0.5°, bp 197.2°, fl p 215°F(101.7°) (closed cup); $n_D$ 1.5536 at 20°; very toxic. Can be prepd by interaction of benzoic acid with sulfurylchloride or by other methods. It is used in medicine, as a reagent and as an intermediate in org reactions
*Refs*: 1)Beil **9**,182,(94) & [159] 2)OrgSynth **24**, 15(1944) 3)CondChemDict(1950),92 4)Sax(1957), 351 5)US Specification MIL-B-11346(Benzoyl Chloride Reagent)

*Mononitrobenzoylchloride*, $C_7H_4ClNO_3$. Three isomers: 2-,3- and 4-Nitrobenzoylchlorides are described in Beil **9**,373,381,394,(162) & [252, 270]

**Dinitrobenzoylchloride**, $C_7H_3ClNO_2O_5$. The following isomers are described in the literature: *2,3-Dinitrobenzoylchloride*, oil(Ref 4,p 3145,footnote); *2,4-Dinitrobenzoylchloride*, ndls (from petr eth), mp 42-6°(Ref 1); *2,6-Dinitrobenzoylchloride*, yel plates(from eth), mp 96-8° (Ref 2); *3,4-Dinitrobenzoylchloride*, $(O_2N)_2C_6H_3.COCl$; solid, mp 45-7°(Ref 4); col ndls (from petr eth), mp 50-1°, bp 188° at 11mm Hg, expl on heating above 225°, easily sol in eth or

benz; diffc sol in petr eth(Ref 5). Was first prepd in an impure state by treating 3,4-dinitro benzoic acid with $PCl_5$(Ref 4). Goldstein & Voegeli prepd it in a pure state by using thionyl chloride in lieu of $PCl_5$ (Ref 5) and

*3,5-Dinitrobenzoylchloride*, ndls(from benz), mp 66-74°, bp 196° at 10-12mm(Ref 3)

*Refs*: 1)Beil **9**,412 2)Beil **9**,413 3)Beil **9**,414 & [283] 4)L.C.Raiford & J.N.Wickert,JACS **53**,3145 (1931) 5)H.Goldstein & R.Voegeli,Helv **26**,477 (1943) & CA **37**, 5709(1943)

**2,4,6-Trinitrobenzoylchloride**, $(O_2N)_3C_6H_2.COCl$; mw 275.57, N 15.25%; ndls(from benz or ligroin), mp 130°(Ref 2); plates(from benz), mp 158°(Ref 3); crysts(from benz by petr eth), mp 163°(Ref 4); sl sol in benz; diffc sol in eth; insol in ligroin or petr eth. Can be prepd by treating 2,4,6-trinitrobenzoic acid with $PCl_5$ or with $POCl_3$. Sudborough (Ref 3) warns of danger of expln during prepn. Expl props of the compd were not investigated

*Refs*: 1)Beil **9**,417 2)V.Meyer,Ber **27**,3145(1894) 3)J.J.Sudborough,JCS **67**,600(1895) 4)P.J. Montagne,Rec **21**,381-2(1902) 5)E.W.Crunden & R.F.Hudson,JCS **1956**,507 & CA **50**,9837(1956) (The rate of solvolysis of 2,4,6-trinitrobenzoylchloride)

**4-[(N-Benzoyl-N-ethyl)-amino]-naphthalene-1-diazonium Hydroxide**[called N-Äthyl-N-benzoylnaphthylamin.(1)-diazoniumhydroxyd.(4) in Ger], $C_6H_5.CO.N(C_2H_5)\text{-}C_{10}H_6.N(:N).OH$; known in the form of salts, such as *Perchlorate*, $C_{19}H_{16}N_3O.ClO_4$, pale yel crysts explg on heating to ca 154° or on impact; was prepd by treating the corresponding sulfate with K perchlorate

*Refs*: 1)Beil **16**,(374) 2)G.T.Morgan & E.G. Couzens,JCS **97**,1695(1910)

**Benzoylhydrazide, Dinitro.** See under Benzoic Acid

**Benzoylhydroperoxide or Benzoylhydrogen Peroxide.** See Perbenzoic(Peroxybenzoic) Acid

**Benzoyliumperchlorate.** See Benzoylperchlorate

### Benzoyl Nitrate and Derivatives

**Benzoyl Nitrate**, $C_6H_5.CO.O.NO_2$; mw 167.12, N 8.38%; yel oil, expl on sudden heating; decomp rapidly by w into benzoic and nitric acids. Can be prepd by the action of Ag nitrate upon benzoylchloride at -15° without presence of any moisture. It is a powerful nitrating agent which shows great tendency to give ortho-substituted products(Refs 3, 4 & 5)

*Refs*: 1)Beil **9**,181 2)F.E.Francis,JCS **89** I,1-4 (1906) & Ber **39**,3798(1906) 3)Sidgwick,OrgChem of N(1937),11-12 4)Houben **4**(1941),216 5)V.Gold, JCS **1950**, 2467-73 & CA **45**,7537(1951) 6)H. Burton & P.F.G.Prail,JCS **1955**,729-31 & CA **50**, 4820(1956) (Investigation of acyl nitrates as a possible source of acylium ion, $RCO^+$)

**3-Nitrobenzoyl Nitrate**, $O_2N.C_6H_4.CO.O.NO_2$; mw 212.12, N 13.21%; crysts, mp 40-50°; expl on sudden heating; can be prepd by the action of Ag nitrate on 3-nitrobenzoylchloride at sl above 35°

*Refs*: 1)Beil **9**,381 2)F.E.Francis,Ber **39**,3800 (1906)

**Benzoyl Nitrite**(called Nitrosylbenzoate in Ref 2), $C_6H_5.CO.O.NO$; mw 151.12, N 9.27%; yel, unstable and hygroscopic oil; expl on sudden heating; can be prepd by treating silverbenzoate in the cold with nitrosylchloride

*Refs*: 1)Beil **9**,181 2)L.Francesconi & U.Cialdea Gazz **34** I,444(1904) & JCS **86** I,707(1904)

**Benzoylperchlorate or Benzoyliumperchlorate.** This compd, prepd *in situ* from equimolecular quantities of benzoylchloride and Ag perchlorate, proved to be an effective benzoylating agent

*Refs*: 1)Beil- not found 2)H.Burton & P.F.G. Prail,JCS **1951**,529 & JCS **1953**,827

**Benzoylperoxide.** See Dibenzoylperoxide

**Benzoylperoxymonosulfonic Acid**(called Benzoylsulfomonopersäure in Ger), $C_6H_5.CO.O.O.SO_3H$; known only in the form of salts, such as *Potassium salt*, $KC_7H_5O_6S$, hygroscopic ndls(from alc), explg mildly on friction or on heating to 70-80°; can be prepd by treating benzoylchloride (previously neutralized by KOH soln) with $K_2SO_5$ soln(or Caro's acid soln neutralized with KOH) at 0°

*Refs*: 1)Beil **9**,181 2)R.Willstätter & E.Hauenstein,Ber **42**,1846(1909)

**(1-Benzoyl-IV-tetrazolyl-5)-isotetrazene; 5-Benzamidotriazeno)-tetrazole 1-Benzoyl-4-tetrazolyl-isotetrazene**, $C_6H_5CO.NH.NH.N{:}N\text{-}\underset{\underset{N}{\|}}{C}\text{-}NH\text{-}\underset{\underset{N}{\|}}{N}$; mw 232.21, N 48.26%; wh ppt, mp 94-8° for the crude product. This high-nitrogen compd was obtd by Scott et al(Ref 2) on adding a soln of 0.01 mol of

tetrazolyldiazonium nitrate to a soln of 0.01 mol of benzohydrazide in aq alc soln in the presence of excess Na acetate soln. As most purification techniques resulted in decompn of this isotetrazene, it was not purified

*Refs*: 1)Beil- not found 2)F.L.Scott,D.A.O'Sullivan & J.Reilly,JACS **75**,5309 & 5312(1953): CA **49**,169(1955)

**Benzozone.** See Acetylbenzoylperoxide in Vol 1, p A54-R

**Benzyl Abietate.** See Vol 1,p A3-R

**Benzylacetyl Peroxide.** See Acetylbenzylperoxide, Vol 1,p A55-L

### Benzyl Alcohol and Derivatives

*Benzyl Alcohol; Phenylmethanol or Hydroxytoluene* (called 1'-Oxy-1-methyl-benzol and ω-Oxy -toluol in Ger), $C_6H_5.CH_2OH$; mw 108.13; col liq, d 1.043 or 20/4°, $n_D$ 1.5403 at 20°, fr p -15.3°, bp 204.7°, fl p 213°F(100.6°) (closed cup); sol in w; misc with alc, eth or chlf. Can be prepd by hydrolysis of benzylchloride with Na or K carbonate in soln or by other methods. There are two commercial products: technical grade and "FFC" (free from chlorine) grade(Ref 3). Toxicity and fire hazard are discussed in Ref 5. It is used extensively in many branches of the chem industries, such as, for the manuf of esters(acetic, benzoic, sebacic, etc), as a solvent for cellulose esters & ethers, etc. During WW I, it was used in a "dope" for airplane fabrics

*Refs*: 1)Beil **6**,428,(217) & [403] 2)OrgSynth **18**, (1938),80 3)Kirk & Othmer **2**(1948),484-6 4)Cond ChemDict(1950),93 5)Sax(1957),352

*Benzyl Nitrite*, $C_6H_5.CH_2.O.NO$; mw 137.13, N 10.21%; unstable oil, bp 80-83° at 35mm. Can be prepd by several methods, such as action of Na nitrite on benzyl alcohol in cold aq sulfuric acid (Ref 1), action of nitric acid+N oxides on $C_6H_5.CH_2.HgCl_2$ at low temp(Ref 2) or treating benzyl bromide with Na nitrite in dimethylformamidine soln contg urea. Infrared spectra detd by Tarte (Ref 1a)

*Refs*: 1)Beil **6**,439 1a)P.Tarte,BullBelg **60**,240 (1951) & CA **46**,826(1952) 2)A.I.Titov & D.E. Rusanov,DoklAkadN **82**,65ff(1952) & CA **47**,2688 (1953) 3)N.Kornblum et al,Chem&Ind **1955**,443 & CA **50**,4805(1956)

*Benzyl Nitrate*, $C_6H_5.CH_2.ONO_2$; mw 153.13, N 9.15%; oil, bp 106° at 20mm; dec explosively at 180-200°. Can be prepd by several methods, such as action of Ag nitrate on benzyl halide(Refs 1 & 3), oxidation of toluene with nitric acid+N oxides(Ref 2), etc

*Refs*: 1)Beil **6**,439 2)A.I.Titov,ZhObshchKhim **18**,534ff(1948) & CA **43**,4216(1949) 3)J.W.Baker & T.G.Heggs,Chem&Ind **1954**,464 & CA **49**, 6872(1955)

*Mononitrosobenzyl Alcohol*, $ON.C_6H_4.CH_2.OH$; mw 137.13,N 10.21%. The 2-Nitrosoalcohol is described in Beil **6**,447 &(222)

*Mononitrobenzyl Alcohol*, $O_2N.C_6H_4.CH_2.OH$; mw 153.13, N 9.15%. The isomers *2-,3- and 4-Nitro* are described in Beil **6**,447,449,450,(222) & [424]

*Nitrobenzyl Nitrite*, $O_2N.C_6H_4.CH_2.O.NO$; mw 182.13, N 15.38%. The *4-Nitro-nitrite* was obtd by Kornblum et al as a yel oil, bp 98° at 2mm Hg, $n_D$ 1.5498 at 20°, on treating p-nitrobenzyl alcohol with Na hydride in dry benz

*Refs*: 1)Beil- not found 2)N.Kornblum et al, JACS **77**,6277(1955) & CA **50**,8492(1956)

**Nitrobenzyl Nitrate**, $O_2N.C_6H_4.CH_2.O.NO_2$; mw 198.13, N 14.14%. The following isomers are known: *2-Nitro-*, solid, mp 28°, prepd by refluxing 2-nitrobenzyl chloride with finely powdered Ag nitrate for 7 days(Ref 4) *3-Nitro-*, pale-yel crysts mp 42.5-43°, prepd as above from 3-nitrobenzyl chloride(Ref 4) and *4-Nitro-*, yel crysts, mp 71° (Ref 1), 52°(Ref 2) and 68.2° (Ref 3); can be prepd by nitration of p-nitrobenzyl alcohol(Refs 1 & 3); by gradual introduction of benzyl nitrate into an excess of 95% nitric acid cooled to -10° (Ref 2) or by refluxing 4-nitrobenzyl chloride with finely powdered Ag nitrate for 7 days (Ref 4). It is a mild expl and Blatt(Ref 3) lists its sensitivity to initiation as follows: "0.4 g undergoes only partial detonation with 0.4 to 0.7 g of 90:10 fulminate-chlorate mixture"

*Refs*: 1)Beil **6**,452 2)Beil **6**,[426] 3)Blatt,OSRD **2014**(1944) 3)J.W.Baker & T.G.Heggs,JCS **1955**, 627 & CA **50**,7081(1956)

**Nitrobenzyl Dinitrate or m-Nitrophenyldinitromethane**, $O_2N.C_6H_4.CH(NO_2)_2$; mw 227.13, N 18.50%; nearly col prisms, mp 128-30°; can be prepd by treating phenyldinitromethane with fuming nitric acid(d 1.5), cooled to -15°(Refs 2 & 3). This isomer of TNT is an expl more powerful than TNT. Its Ag, Amm, Ba, K & Pb salts are powerful expls(Ref 2)

*Refs*: 1)Beil- not found 2)M.Milone & A.Massa, Gazz **70**,196(1940) & CA **34**,4571(1940) 3)L. Fieser & W.von E.Doering,JACS**68**,2253(1946) &

CA **41**,733(1947)

**Dinitrobenzyl Alcohol,** $(O_2N)_2C_6H_3.CH_2OH$; mw 198.13, N 14.14%. The following isomers are described in the literature: *2,4-Dinitrobenzyl Alcohol,* lt yel ndls(from w), mp 114-5°; easily sol in alc or AcOH; insol in ligroin; can be prepd by treating 2,4-dinitrobenzyl acetate with aq sulfuric acid(1:1)(Refs 1 & 3). Its expl props were not investigated and *2,6-Dinitrobenzyl Alcohol,* brownish plates(from ether), mp 94°; can be prepd by heating 2,6-dinitrobenzyl bromide with w(Refs 2 & 4). Its expl props were not investigated

*Refs*: 1)Beil **6**,453 & [426] 2)Beil **6**,(224) & [426] 3)P.Cohn & P.Friedländer, Ber **35**,1266(1902) 4)S.Reich et al,Ber **45**,3058(1912) 5)G.Williams & D.J.Clark,JCS **1956**,1304 & CA **50**,16697(Esterification of 2,4-nitrobenzyl alcohol with aq sulfuric acid)

**Dinitrobenzyl Nitrate**(DNBzlN) $(O_2N)_2C_6H_3.CH_2.ONO_2$; mw 243.13, N 17.28%, OB to $CO_2$ -62.5%. The isomer *2,4-Dinitro-*, crysts, d 1.55 at 25°, mp 38.8°, expl ca 180°(in 5 mins). It was prepd prior to 1944 by the DuPont Co through the following steps: Benzyl chloride→ 2,4-dinitrobenzyl chloride→ 2,4-dinitrobenzyl alcohol→ 2,4-dinitrobenzyl nitrate

DNBzlN is an expl about 70% as powerful as NG(by the Trauzl Test) and fairly stable in storage at 60 & 75°. It can be detonated by a hammer blow but not from the impact of an 8-oz wt falling from a height of 25"(Ref 2)

*Refs*: 1)Beil-not found 2)Blatt,OSRD **2014**(1944)

*Note:* No other Refs were found for DNBzlN

**Trinitrobenzyl Alcohol,** $(O_2N)_3C_6H_2.CH_2.OH$; mw 243.13, N 17.28%. One isomer, *2,4,6-Trinitrobenzyl Alcohol,* is described in the literature. It was first obtained by Reich et al(Ref 2) on heating 2,4,6-trinitrobenzylbromide with water, as brn ndls(from benz + ligroin), mp 100°; easily sol in alc, benz or ether; moderately sol in hot w; diffc sol in chlf or $CS_2$; insol in ligroin. Ganguly(Ref 3) prepd the same compd(mp 100°) by refluxing 2,4,6-trinitrobenzylbromide with w for 6 hrs. Fieser & Doering(Ref 4) prepd it as yel prisms, mp 118-20° by nitration of benzyl alc with fuming nitric acid(d 1.5), previously chilled to -15°. Its expl props were not investigated

*Refs*: 1)Beil **6**,(224) & [426] 2)S.Reich et al,Ber **45**,3058(1912) 3)K.L.Ganguly,Ber **58**,712(1925) 4)L.Fieser & W.von E.Doering,JACS **68**,2253 (1946) & CA **41**,733(1947)

**2,4,6-TRINITROBENZYL NITRATE**(TNBzlN), $(O_2N)_3C_6H_2.CH_2.O.NO_2$; mw 288.13, N 19.45%, OB to $CO_2$ -38.9%, OB to CO 0.0%; col prisms, mp 118.5-119.5°, d(cryst) 1.5; insol in w, sl sol in ether; sol in acet or methanol. Can be prepd by nitration of 2,4,6-trinitrobenzyl alcohol(see above) with fuming nitric acid(d 1.5), but this method is less satisfactory than treating 2,4,6-trinitrobenzylbromide with Ag nitrate in acetonitrile soln(Refs 2,5 & 6)

TNBzlN is an expl about as powerful as tetryl (ca 126-7% TNT by Ballistic Mortar Test) and sl less sensitive to impact than PETN. It possesses adequate stability and favorable oxygen balance to CO: $C_7H_4N_4O_9 \rightarrow 7CO + 2H_2O + 2N_2$

Its expl and other props, given in Refs 2,3,4 & 5), are as follows: *Ballistic Mortar Value* (Power) 127% TNT; *Explosion Temperature* ignites ca 340°, but does not expl even at 360° (same as for TNT); *Friction Sensitivity*- sl less sensitive than RDX; *Heat of Combustion,* $Q_c$ 769.8 kcal/mole; *Heat of Explosion,* $Q_e$ 272.6 kcal/mole; *Heat of Formation,* $Q_f$ 27.8 kcal/mol; *Hygroscopicity*- increase in wt at 100% RH 0.09% vs 0.03% for TNT; not hygroscopic at 90% RH; *Impact Sensitivity*, detd by BurMinesApp No 5- sl less sensitive than PETN; 75° *International Heat Test*- loss of wt in 48 hrs 0.1% vs 0.2% for TNT; *Power*- see Ballistic Mortar Value and Trauzl Value; *Stability, Thermal at 100°*- no expln in 300+ mins(same as for TNT); *Stability, Thermal at 135°*- methyl violet turned salmon pink in 30 mins vs 300+ mins for TNT; *Temperature of Explosion* 3885°K; *Trauzl Test Value* 135% TNT

*Uses*- no information at our disposal

*Remark*: According to Ref 5, TNBzlN is a precursor of the *White Compound* [See 2,2'-Azoxybis (4,6-dinitrobenzoic acid) under Dinitrobenzoic Acid] an oxidative by-product in the manuf of TNT by continuous method

*Refs*: 1)Beil- not found 2)L.Fieser,OSRD **176** (1941),27-38 3)G.B.Kistiakowsky,OSRD **702** (1942) 4)R.McGill,OSRD **830**(1942) 5)Blatt,OSRD **2014**(1944) 6)L.F.Fieser & W.von E.Doering, JACS **68**,2252(1946 & CA **41**,733(1947)

**Tetranitrobenzyl,** $C_7H_3N_5O_{11}$- not found in Beil or in CA thru 1956

### Benzylamine and Derivatives

*Benzylamine*(called 1'-Amino-1-methyl-benzol and ω-Amino-toluol in Ger), $C_6H_5.CH_2.NH_2$; mw 107.15, N 13.07%, liq, d0.982 at 20/4°, bp 184.5°;

misc with w, alc or eth. Other props and prepn in Beil **12**,1013(445) & [540] (Compare with Aminotoluene in Vol 1,A264-L)

*Benzylamine Nitrate*, $C_7H_9N + HNO_3$; mw 170.17, N 16.46%; pltlts, mp 136-138.5°, $Q_c^p$ 942.7kcal/mol, $Q_f$ 57.2kcal/mol; can be prepd by neutralizing benzylamine with 70% nitric acid and removing w by distn in vacuo

*Refs*: 1)Beil **12**,1018 2)T.L.Cottrell & J.E.Gill, JCS **1951**,1798-9 & CA **45**,10028(1951)

**Benzylamine Perchlorate**, $C_7H_9N + HClO_4$, solid, mp 120°, expl at 305°

*Refs*: 1)Beil **12**,(466-7) 2)R.L.Datta & N.R. Chatterjee,JCS **115**,1009(1919)

**Benzylamine Picrate**, $C_7H_9N + C_6H_3N_3O_7$; mw 336.26, N 16.66%; lt yel crysts, mp 194-9°, d 1.536; can be prepd by adding benzylamine to an equi amt of PA in boiling w. Its expl props were not investigated

*Refs*: 1)Beil **12**,1018 2)C.Moureau & I.Lazennec, CR **143**,553(1906) 3)G.Jerusalem,JCS **95**,1283 (1909)

*Mononitrobenzylamine*, $O_2N.C_6H_4.CH_2.NH_2$; mw 152.15, N 18.41%. All three isomers, *2-, 3-, and 4-Nitro*, are described in Beil **12**,1076,1083,1084, (466) & [576,578,580]

*Benzylnitramine*, $C_6H_5.CH_2.NH.NO_2$; mw 152.15, N 18.41%, ndls, mp 38-9°, is described in Beil **16**,(396)

**Nitrobenzylnitramine**, $O_2N.C_6H_4.CH_2.N.NO_2$; mw 197.15, N 21.32%. The isomer *4-Nitro*, crysts (from benz or from aq alc), mp 116°; was prepd from benzylurethane as described in Refs 1 & 2. Its expl props were not detd

*Refs*: 1)Beil **16**,673 2)A.Hantzsch,Ber **31**,181 (1898)

**Dinitrobenzylamine**, $(O_2N)_2C_6H_3.CH_2.NH_2$; mw 197.15, N 21.32%. Its *2,6-Dinitro-isomer*, brn ndls, mp 88°, is described in Ref 1, while the *2,4-Dinitro-isomer*, brn ppt, mp 179°, it described in Ref 2. Their expl props were not detd

*Refs*: 1)Beil **12**,467 2)K.A.de Vries,Rec **61**,236 & 238(1942) & CA **38**,2313(1944)

*Dinitrobenzylnitramine*, $(O_2N)_2C_6H_3.CH_2.NH(NO_2)$ and *Trinitrobenzylnitramine*, $(O_2N)_3C_6H_2.CH_2.NH(NO_2)$- not found in Beil or in CA thru 1956

**1-Benzyl-5-amino-vic-tetrazole.** See 5-Amino-1-Benzyl-vic-tetrazole; Vol 1,p A191-L

### Benzylaniline and Derivatives

*Benzylaniline or Phenylbenzylamine*, $C_6H_5.CH_2NH.C_6H_5$; mw 183.24, N 7.64%; monocl prisms, mp 37-8°, bp 306° at 759mm. Other props & prepn are given in Beil **12**,1023(449) & [548]

*Note:* Nitration of benzylaniline and of its derivatives is discussed by P.van den Berg,Rec **55**,241-53 & 1053-67(1936)

*Mononitrobenzylaniline*, $C_{13}H_{12}N_2O_2$; mw 228.24, N 12.27%. Several isomers are described in Beil **12**,1024,1076,1083,1085,(466) & [549,577,579, 581] and by P. van den Berg,Rec **55**,848

*Dinitrobenzylaniline*, $C_{13}H_{11}N_3O_4$; mw 273.24, N 15.38%. Several isomers are described in Beil **12**,1024,1077, 1085, 1086, 1088, 1089, (450, 467) & [549, 762] and by P. van den Berg,Rec **55**,842, 843, 844, 849, 850 & 1061

**Trinitrobenzylaniline**, $C_{13}H_{10}N_4O_6$; mw 318.24, N 17.61%. The following isomers are described in the literature:

*N-Benzyl-2,4,6-trinitro-aniline, 2,4,6-Trinitro-N-benzylaniline or N-Picrylbenzylamine*, $C_6H_5CH_2.NH.C_6H_2(NO_2)_3$; yel ndls, mp 144.8°(Ref 2); crysts, mp 143°(Ref 4); crysts(from alc+dioxane), mp 142°(Ref 5). Can be prepd by warming methylpicrylnitramine with benzylamine in alc(Ref 2) or by adding, dropwise, benzylamine to a boiling alc soln of picrylchloride(Refs 3 & 4). This compd was also prepd by Leandri & Tundo(Ref 5). Its expl props were not detd

*Refs*: 1)Beil **12**, [549] 2)T.C.James et al,JCS **117**,1275(1920) 3)M.M.Cullinane et al,JCS **1932** 2363 4)P. van den Berg,Rec **55**,845(1936) 5)G. Leandri & A.Tundo, AnnChim(Rome) **44**,479-88 (1954) & CA **49**,15783(1955)

*N-(2,4,6-Trinitrobenzyl)-aniline or Phenyl-(2,4,6-trinitrobenzyl)-amine*, $(O_2N)_3C_6H_2.CH_2.NH.C_6H_5$; brn ndls, mp 151°; can be prepd by heating 2,4,6-trinitrobenzenebromide with aniline in benz. Its expl props were not detd

*Refs*: 1)Beil **12**,(468) 2)S.Reich et al,Ber **45**, 3058(1912)

*4'-Nitrobenzyl-2,4-dinitroaniline*, $O_2N.C_6H_4.CH_2NH.C_6H_3(NO_2)_2$; brn ndls, mp 186°; easily sol in acet & warm AcOH; sl sol in alc, benz or chlf; v sl sol in ether or petr eth. Its method of prepn, starting from 4-nitrobenzylchloride and ammonia, is described in Ref 2

*Refs*: 1)Beil- not found 2)P. van den Berg,Rec **55**,845-6(1936)

**Tetranitrobenzylaniline**, $C_{13}H_9N_5O_8$; mw 363.24, N 19.28%. The following isomers are described in the literature:

*N-(2,4,6-Trinitrobenzyl)-3-nitroaniline or (3-Nitrophenyl)-(2,4,6-trinitrobenzyl)-amine*, $(O_2N)_3C_6H_2CH_2.NH.C_6H_4.NO_2$; red ndls, mp 153°; was prepd

by heating 2,4,6-trinitrobenzylbromide with 3-nitroaniline in benz. Its expl props were not detd
*Refs*: 1)Beil **12**,(468) 2)S.Reich et al, Ber **45**, 3059(1912)

4'-Nitrobenzyl-2,4,6-trinitroaniline, $O_2N.C_6H_4.CH_2.NH.C_6H_2(NO_2)_3$, red-brn solid, mp 191°; easily sol in acet; less sol in chlf, benz or warm AcOH; sl sol in alc; v diffc sol in eth or petr eth. Was prepd by mixing alc solns of 4-nitrobenzylamine and picrylchloride and boiling the mixt for 15 mins on a water bath. Its expl props were not detd
*Refs*: 1)Beil- not found 2)P.van den Berg,Rec **55**,846(1936)

**Pentanitrobenzylaniline,** $C_{13}H_8N_6O_{10}$; mw 408.24, N 20.59%, OB to $CO_2$ -78.4%. The following isomers are known:

*2'-Nitrobenzyl-2,4,6-trinitro-nitraniline or 2'-Nitrobenzyl-2,4,6-trinitrophenyl-nitramine,* $O_2N.C_6H_4.CH_2.N(NO_2).C_6H_2(NO_2)_3$; col crysts(from alc+acet), mp 149°(with evoln of gas); easily sol in acet or warm AcOH; less sol in benz; sl sol in alc or chlf; nearly insol in eth, petr eth or w. Was prepd by nitrating 2'-nitrobenzyl-4-nitroaniline or 2'-nitrobenzyl-2-nitroaniline with nitric acid(d 1.46). Its expl props were not detd(Ref 2, pp 850 & 853)

*3'-Nitrobenzyl-2,4,6-trinitro-nitraniline,* almost col crysts(from alc+acet), mp 149°(with evoln of gas), easily sol in acet or boiling AcOH; moderately sol in warm benz; less sol in alc, chlf, eth & petr eth. Was prepd by nitrating 3'-nitrobenzyl-4-nitroaniline with abs nitric acid as described in Ref 2,p 1062. Its expl. props were not detd
*Refs*: 1)Beil- not found 2)P.van den Berg,Rec **55**,850,853 & 1062(1936)

*4'-Nitrobenzyl-2,4,6-trinitro-nitraniline; 4'-Nitrobenzyl-2,4,6-trinitrophenyl-nitramine or Picryl-(4-nitrobenzyl)-nitramine;* nearly col crysts, mp 141-2° (with evoln of gas); was first prepd by Blanksma(Ref 2) by heating N-(4-nitrobenzyl)-4-nitroaniline with nitric acid(d 1.52) and then later by van den Berg(Ref 3), who showed that this compd can also be obtd by nitration of 4'-nitrobenzyl-2-nitroaniline, benzyl-2,4-dinitroaniline, benzyl-2,4,6-trinitroaniline, 4'-nitrobenzyl-2,4-dinitroaniline or 4'-nitrobenzyl-2,4,6-trinitroaniline. Its expl props were not detd
*Refs*: 1)Beil **12**,1089 2)J.J.Blanksma,Rec **21**, 429(1902) 3)P.van den Berg,Rec **55**,843-7(1936)

**Hexanitrobenzylaniline,** $C_{13}H_7N_7O_{12}$; mw 453.24, N 21.63%, OB to $CO_2$ -61.8%. The following isomer is known:

*2',4'-Dinitrobenzyl-2,4,6-trinitro-nitraniline; 2',4'-Dinitro-benzyl-2,4,6-trinitrophenyl-nitramine or Picryl-(2,4-dinitrobenzyl)-nitramine,* $(O_2N)_2C_6H_3.CH_2.N(NO_2).C_6H_2(NO_2)_3$; nearly col crysts(from alc+acet), mp 150-1°(with evoln of gas); easily sol in acet; moderately sol in warm AcOH; diffc sol in alc, benz or chlf; insol in eth or petr eth. Can be prepd by nitration of 2'-nitrobenzyl-2,4,6-trinitronitraniline with abs nitric acid or by nitration of 4'-nitrobenzylaniline (or of benzyl-4-nitroaniline) with mixed nitric-sulfuric acid. Its expl props were not detd
*Refs*: 1)Beil- not found 2)P.van den Berg,Rec **55**,848-9(1936)

*2',4',6'-Trinitrobenzyl-2,4,6-trinitro-nitraniline,* $(O_2N)_3C_6H_2.CH_2.N(NO_2).C_6H_2(NO_2)_3$; mw 498.24, N 22.49%-not found in Beil or in CA thru 1956

## Benzylazide and Derivatives

**Benzylazide**(called 1'-Azido-1-methyl-benzol, ω-Azido-toluol and ω-Triazo-toluol in Ger), $C_6H_5.CH_2.N_3$; mw 133.15, N 31.56%; oil, d 1.0655 at 24.5°, $n_D$ 1.53414 at 24.9°, bp 82.5° at 16.5mm; expl on strong heating with evoln of flame; also expl on contact with concd sulfuric acid. Insol in w, miscible with alc or eth; vol with steam or with ether. Can be prepd by treating benzyl chloride with Na azide in alc or by other methods
*Refs*: 1)Beil **5**,350,(174) & [274] 2)T.Curtius, Ber **33**,2562(1900) 3)J.C.Phillip,JCS **93**,919 (1908) 4)T.Curtius & G.Ehrhart,Ber **55**,1565 (1922)

**Mononitrobenzylazide,** $O_2N.C_6H_4.CH_2.N_3$; mw 178.15, N 31.45%, OB to $CO_2$ -134%. Prepn of o- and p-nitrobenzyl azides from Na(or Ag) azide and the appropriate chlorides or iodides in alc or ether for 8-10 hrs at the bp, was described by Yushchenko(Ref 2). He gave the bp of o- as 121-2° at 2mm and of p- as 144-8° at 2mm. The DuPont Co prepd, sometime before 1944, an impure p-nitrobenzylazide by treating benzylchloride with Na azide. The product had mp ca 5° and could not be detonated by a 2-g steel ball falling 25" (Ref 3)
*Refs*: 1)Beil- not found 2)Yu.Yushchenko,Mem-InstChemUkrainAcadSci **2**,195(1935) & CA **31**, 3467(1937) 3)Blatt,OSRD **2014**(1944), under Azides

**Dinitrobenzylazide,** $(O_2N)_2C_6H_3.CH_2.N_3$; mw 223.15, N 31.39%. Its *2,4-Dinitro-* isomer is a

solid, melting at 46-7°. It was prepd by Yushchenko by treating 2,4-dinitrobenzylchloride with Na(or Ag) azide in alc(or ether) for 8-10 hrs at the bp. Its expl props are not described in CA
*Refs*: 1)Beil- not found 2)Yu.Yushchenko,Mem InstChemUkrainAcadSci **2**,195(1935) & CA **31**, 3467(1937)
*Trinitrobenzylazide*, $(O_2N)_3C_6H_2.CH_2.N_3$- not found in Beil or in CA thru 1956

**Benzylazidodithiocarbonate.** See Vol 1,p A633-L

### Benzylbenzoate and Derivatives

*Benzylbenzoate(Benzyl Ester of Benzoic Acid)* (called Benzoesäurebenzylester or Benzylbenzoat in Ger), $C_6H_5CO_2.CH_2.C_6H_5$; mw 212.24, O 15.08%, OB to $CO_2$ -241%; liq at RT, ndls or lfts on prolonged cooling, fr p 19.4-21°, bp 324° at 760mm, dec on heating for 2hrs at 340-50°, d 1.112 at 25°; sol in acet, alc, AcOH, chlf, $CS_2$, eth, benz, MeOH, petr eth or xylol; insol in w or glycerin; toxicity discussed by Sax(Ref 3); can be prepd by heating benzoic acid with benzyl alcohol at the bp or in the presence of tin at 200°. Other props and methods of prepn are given in Ref 1

Davis(Ref 2) reported its possible use as a gelatinizer for NC
*Refs*: 1)Beil **9**,121,(68) & [100] 2)Davis(1943), p 320 3)Sax(1957),p 353
*Benzyl Mononitrobenzoate*, $O_2N.C_6H_4.CO_2.CH_2.C_6H_5$; mw 257.24, N 5.45%. One isomer, *4-Nitro-* is described in Beil **9**, 392
*Mononitrobenzyl Mononitrobenzoate*, $O_2N.C_6H_4.CO_2.CH_2.C_6H_4.NO_2$; mw 302.24, N 9.27%. The following isomers are described in the literature: *2-Nitrobenzyl-2-nitrobenzoate*, crysts, mp 104-6° (Ref,p 373)
*3-Nitrobenzyl-3-nitrobenzoate*, yel crysts, mp 143-4° (Ref,p 379) *4-Nitrobenzyl-4-nitrobenzoate*, yel crysts, mp 168-172° [Ref,p 392 & (159)] *4-Nitrobenzyl-2-nitrobenzoate*, crysts, mp 111.8° [Ref,p (159)] and *4-Nitrobenzyl-3-nitrobenzoate*, crysts, mp 141.5° [Ref,p(154)]
*Ref*: Beil **9**,373,379,392 & (152,154,159)
**Dinitrobenzyl Benzoate**, $C_6H_5.CO_2.CH_2.C_6H_3(NO_2)_2$; mw 302.24, N 9.27%. Only the *2,4-Dinitrobenzyl-benzoate* is described in the literature: yel ndls(from glac AcOH), mp 141°; insol in alc, eth, benz or w; was prepd by the action of K benzoate on 2,4-dinitrobenzyl chloride in boiling methanol or ethanol

The gelatinizing props of benzyl benzoate suggest that nitro or dinitro derivs may also be used as gelatinizing agents for NC
*Refs* 1)Beil **9**,[101] 2)K.A.Krassukii & A.H. Plissov,UkrainskiiKhemZhurnal **1**,640(1925); ChemZtr **1926** II,193 & CA **21**,2457(1927)
**Mononitrobenzyl Dinitrobenzoate**, $(O_2N)_2C_6H_3CO_2.CH_2.C_6H_4.NO_2$; mw 374.24, N 12.10%. Only the *4-Nitrobenzyl-2,4-dinitrobenzoate* is described in the literature: crysts(from boiling alc), mp 142°; very sl sol in boiling alc; was prepd by heating the Na salt of 2,4-dinitrobenzoic acid with 4-nitrobenzyl bromide in boiling alc. Its expl props were not detd
*Refs*: 1)Beil **9**,(166) 2)E.M.Reid,JACS **39**,133 (1917)
*Tetranitro-* $C_{14}H_8N_4O_{10}$, *Pentanitro-* $C_{14}H_7N_5O_{12}$ and *Hexanitro-* $C_{14}H_6N_6O_{14}$ *Derivatives of Benzyl Benzoate* were not found in Beil or in CA thru 1956

### Benzyl Chloride and Derivatives

*Benzyl Chloride; ω-Chlorotoluene or 1'-Chloro-1-methyl-benzene*, $C_6H_5.CH_2.Cl$; col liq with pungent odor, d 1.00 at 20/20°, fr p -39°, bp 179.4°; misc with alc, eth or chlf; insol in w. Other props and various methods of prepn are discussed in Ref 1; its toxicity, fire & expln hazards are given in Ref 2
*Refs*: 1)Beil **5**,292,(151) & [227] 2)Sax(1957), 353
*Note: F.Oehme,ChemTech* **4**,404(1952) & *CA* **47**, 1277(1953)(During distn of the tech product, HCl was evolved and air was bubbled through the soln to remove HCl. Suddenly, an expln occurred and the reaction mass became an orn-grn, fluorescent, very viscous mass)
*Mononitrobenzyl Chloride*, $C_7H_6ClNO_2$. The isomers: 2-,3-, and 4-Nitrobenzylchlorides, are described in Beil **5**,327-31,(162-3) & [252-4]
**Trinitrobenzyl Chloride**, $C_7H_4ClN_3O_6$; mw 261.58, N 16.06%, OB to $CO_2$ -61.1%. The isomer, *2,4,6-Trinitrobenzyl Chloride or ω-Chloro-2,4,6-trinitrotoluene*, $(O_2N)_3C_6H_2.CH_2.Cl$; crysts(from alc), mp 85°; v sol in benz or eth; sol in hot alc; insol in w or cold alc, was obtained in small quantity by Ganguly on prolonged heating in a sealed tube at 150-60°, of 2,4,6-TNT with $PCl_5$ and some iodine. Its expl props were not detd
*Refs*: 1)Beil **5**,[272] 2)K.L.Ganguly,Ber **58**,711 (1925)
*Tetranitrobenzyl Chloride*, $C_7H_3ClN_4O_8$- not found in Beil or in CA thru 1956

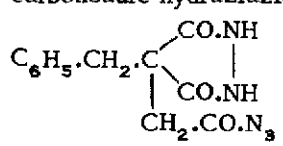
### Benzyl Cyanide and Derivatives

*Benzyl Cyanide or Phenyl Acetonitrile* (called

Benzylcyanid, Phenylacetonitril or Phenylessigsäure-nitril in Ger), $C_6H_5.CH_2.CN$; mw 117.14, N 11.96%; oily liq with aromatic odor, fr p -23.8°, bp 233.5°, d 1.021 at 15°; toxicity is discussed in Sax(Ref 2); other props & prepn are given in Beil(Ref 1)
*Refs*: 1)Beil **9**,441,(176) & [302] 2)Sax(1957), 355 & 521
*Mononitrobenzyl Cyanide*, $O_2N.C_6H_4.CH_2.CN$; mw 162.14, N 17.28%. Three isomers 2-,3- and 4-Nitrobenzyl Cyanides are described in Beil **9**,455,456,(182,183) & [311,312,313]
**Dinitrobenzyl Cyanide**, $(O_2N)_2.C_6H_3.CH_2.CN$; mw 207.14, N 20.29%. Two isomers are described in the literature: *2,4-Dinitrobenzyl Cyanide*, yel ndls(from $CCl_4$), mp 89° and *2,6-Dinitrobenzyl Cyanide*, yel-brn crysts(from nitrobenz+alc), mp 202°. Other props and their prepn are given in Beil **9**,(185) & [315]. These compds are evidently expl but this was not detd
*Trinitrobenzyl Cyanide*, $C_8H_4N_4O_6$- not found in Beil or in CA thru 1956

**Benzyldimethylhexadecylammonium Chloride**, $C_6H_5.CH_2(CH_3)_2.N(C_{16}H_{33})Cl$. A quaternary ammonium halide recommended by McDonald(Ref 2) as satisfactory for the decontamination of waters contg dissolved expl wastes. This, or other halide salts, can be added to a tank along with the waste water; the expl material settles as an insol addn compd
*Refs*: 1)Beil- not found 2)L.McDonald,USP 2647084(1953) & CA **47**,10853(1953)

**4-Benzyl-3,5-dioxo-4-pyrazolidineacetyl Azide or α-Phenylpropane-β,β,γ-tricarboxylic Hydrazoazide** (called α-Phenyl-propan-β,β,γ-tricarbonsäure hydraziazid by Curtius),



; mw 273.25, N 25.63%;
lt yel pdr, mp dec at 202-3° with evoln of gas; defgr when heated on a Pt foil in flame; could not be obtained in cryst state because it is insol in neutral solvents such as eth, benz or chlf and is decompd by solvents such as alc. Can be prepd by adding dropwise aq $NaNO_2$ soln to the corresponding hydrazohydrazide dissolved in cold dil HCl
*Refs*: 1)Beil- not found 2)T.Curtius & W.Sandhaas,JPraktChem **125**,93 & 100-1(1930) & CA **24**,3231(1930)

**Benzyldiphenylamine or Diphenylbenzylamine**, $C_6H_5CH_2.N(C_6H_5)_2$; mw 259.33, N 5.40%, OB to CO -138.9%; col ndls, mp 86-87°; sol in acet, eth, chlf, benz & hot alc; diffc sol in AcOH & cold alc; v sl sol in w. Other props & prepn are described in Ref 1. Because this compd may be suitable as an ingredient of propellants, Tavernier & Lamorous detd its calorimetric props. They gave $Q_C^V$ 2413.8kcal/mol, $Q_C^P$ 2415.98kcal/mol, $Q_f^V$ -44.4kcal/mol and $Q_f^P$ -39.1kcal/mol
*Refs*: 1)Beil **12**,1033 & [551] 2)P.Tavernier & M.Lamouroux,MP **38**,77 & 84(1956)

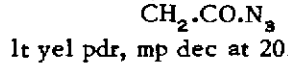
**Benzylester of Benzoic Acid.** See Benzyl Benzoate

**Benzylester of Peracetic Acid.** See Acetylbenzylperoxide, Vol I,p A55-L

**Benzylethylene Ozonide** (called 1-Phenyl-α-propylen-ozonid, Phenylallyl-ozonid or Allylbenzol in Ger). The *monomeric ozonide*, $C_9H_{10}O_3$, liq, bp 67-71° at 0.4-0.8mm, d 1.1362 at 21/21°, was obtained together with the dimeric form by treating allylbenzene, $C_6H_5.CH_2.CH{:}CH_2$, in $CCl_4$ soln with purified ozone. It is a weak expl, difficultly sol in w. The *dimeric ozonide*, $(C_9H_{10}O_3)_2$, was septd from the monomeric ozonide by dissolving the reaction mixture in acet eth and pptg with petr eth. It is a syrupy liq, d 1.766 at 21/21°, $n_D$ 1.5422, which decompd ca 100° and exploded violently at 104-6°. More diffc sol in w than the monomer
*Refs*: 1)Beil **5**,(233) 2)C.Harries,Ann **390**,261-3 (1912)

**Benzylic Acid.** Same as Phenylacetic Acid

**1-Benzylideneamino-5-amino-α(or 1H)-tetrazole; 5-Amino-1-benzylideneamino-1,2,3,4-tetrazole or 1-Benzalamino-5-aminotetrazole**,



; mw 188.19, N 44.66%;
fine ndls, mp 210° (with rapid evoln of gas); moderately sol in hot alc; diffc sol in eth; insol in w; was prepd by shaking for 8 hrs a mixt of thiosemicarbazide, Na azide and Pb oxide in boiling alc. It might be suitable as an ingredient of propellants
*Refs*: 1)Beil- not found 2)R.Stollé & E.Gaertner, JPraktChem **132**,210 & 214(1931) & CA **26**,1607 (1932)

**1-Benzylideneamino-5-anilino-α(or 1H)-tetrazole, 1-Anilino-1-benzylideneamino-1,2,3,4-tetrazole or 1-Benzalamino-5-anilino-tetrazole** (called Benzalamino-1-anilino-5-tetrazol by Stollé), $C_6H_5.NH.C\text{-}N(N{:}CH.C_6H_5)\text{-}N$; mw 264.28, N 31.80%; ndls or lfts(from alc), mp 216°; sl sol in eth & alc; insol in w; was prepd by shaking for 12 hrs a mixt of 4-thiosemicarbazide, Na azide and Pb oxide in boiling alc, while bubbling in $CO_2$. Its expl props were not investigated

*Refs*: 1)Beil- not found 2)R.Stollé & E.Gaertner, JPraktChem **132**,210 & 214(1931) & CA **26**,1608 (1932)

**Benzylideneaminophenol and Derivatives**

*Benzylideneaminophenol or Benzalaminophenol*, (called Benzylideneamino-phenol or Benzalamino -phenol in Ger), $C_6H_5.CH{:}N.C_6H_4.OH$; mw 197.23, N 7.10%. This compd exists in two isomeric forms: *2-Benzalaminophenol*, lfts(from alc), mp 89° (Ref 1) and *4-Benzalaminophenol*, lfts(from dil alc), mp 183°; its *Hydrochloride salt*, $C_{13}H_{11}NO{+}HCl$, yel ndls, dec ca 132° (Ref 2). Other props and methods of prepn are given in Refs

*Refs*: 1)Beil **13**,368 & (312) 2)Beil **13**,453,(155) & [236]

*4-(4-Azidobenzylideneamino)-phenol*, $N_3.C_6H_4.CH{:}N.C_6H_4.OH$; mw 238.24, N 23.52%; golden -brn plates(from benz), mp 175° (dec); readily sol in hot acet or eth acet; sol in boiling MeOH; sl sol in boiling benz; was prepd by mixing aq p -aminophenol hydrochloride, Na acetate and p -azidobenzaldehyde

*Refs*: 1)Beil **13**,(155) 2)M.O.Forster & H.M.Judd, JCS **97** I,260(1910)

*Mononitrobenzylideneaminophenol*, $O_2N.C_6H_4.CH{:}N.C_6H_4.OH$; mw 242.23, N 11.57%. The nine possible *isomers* of 2,3 or 4-Mononitrobenzylideneamino-phenol with the substituted mononitroderiv in ortho(or 2)-, meta(or 3)-, and para(or 4)- positions with respect to the hydroxy group of phenol, have all been prepd and described in the literature

*Ref*: 1)Beil **13**,368,414,453,(133,135) & [236]

*Dinitrobenzylideneaminophenol*, $(O_2N)_2C_6H_3.CH{:}N.C_6H_4.OH$; mw 287.23, N 14.63%. Only the *4-(2,4-Dinitrobenzylideneamino)-phenol* is described in the literature: yel crysts(from alc), mp 158°; was prepd by heating 4-aminophenol with 2,4-dinitrobenzaldehyde in alc glac AcOH

*Refs:* 1)Beil **13** [236] 2)G.M.Bennett & W.L.C. Pratt, JCS **1929**, 1466

**4-(2,4,6-Trinitrobenzylideneamino)-phenol**, $(O_2N)_3.C_6H_2.CH{:}N.C_6H_4.OH$(?); mw 332.23, N 16.87%; yel crysts(from alc) sensitive to light, mp 179°; was prepd by condensation of 4-aminophenol and 2,4,6-trinitrobenzaldehyde in glac AcOH, on a w bath. Its expl props were not detd

*Refs:* 1)Beil **13**, [236] 2)A.Lowy & E.H.Balz, JACS **43**,345(1921)

*Tetranitro-*$C_{13}H_7N_5O_9$ and *Pentanitro-*$C_{13}H_6N_6O_{11}$*Benzylideneaminophenols* were not found in Beil or in CA thru 1956

**1-Benzylideneamino-5-phenyl-α(or 1H)-tetrazole.** See 1-Benzal-amino-5-phenyl -α(or 1H)-tetrazole

**5-Benzylideneamino-2-phenyl-β(or 2H)-tetrazole.** See 5-Benzalamino-2-phenyl-β(or 2H)-tetrazole

**Benzylideneaniline and Derivatives**

*N-Benzylideneaniline or Benzalaniline* (called Benzaldehyde-anil in Beil), $C_6H_5.CH{:}N.C_6H_5$; mw 181.23, N 7.73%; yel crysts; mp-melts at first at 48-9° and then, after solidification, remelts at 54-56° (the difference in mp's is probably due to several modifications of the compd); bp ca 300°, d 1.0739 at 50/13°; volatilized by steam. Other props & prepn are given in Refs. Forms salts, some of which are probably expl, eg *Perchlorate*, crysts, mp 179° (Ref 1,p [170]

*Refs*: 1)Beil **12**,195,(169) & [113] 2)OrgSynth CollVol **1**(1941),73

*Mononitrobenzylideneaniline*, $C_{13}H_{10}N_2O_2$; mw 226.23, N 12.38%. Its 2-,3- and 4-Nitro-isomers are described in Beil **12**,702,717,(346,351) & [370]

*Dinitrobenzylideneaniline*, $C_{13}H_9N_3O_4$; mw 271.23, N 15.49%. Eight isomers are described in Beil **12**, 199,702,(172, 346) & [370, 372, 378 & 388]

**Trinitrobenzylideneaniline**, $C_{13}H_8N_4O_6$; mw 316.23, N 17.72%. The following isomers are described in the literature:

*N-(2,4,6-Trinitrobenzylidene)-aniline*, $(O_2N)_3C_6H_2.CH{:}N.C_6H_5$; reddish, small ndls(from alc), mp 162° (Refs 1 & 2); 171°(Ref 3); easily sol in benz; diffc sol in alc; insol in w; was prepd by heating 2,4,6-trinitrobenzaldehyde with aniline in alc soln(Refs 1 & 2) or on interaction of the same substances in cold AcOH(Ref 3)

*Refs:* 1)Beil **12**,199 & [114] 2)F.Sachs et al, Ber **36**,961(1903) & **39**, 2761(1906) 3)S.Secareanu, BullFr **51**,591(1932) & CA **26**,5081(1932)

*N-(2,4-Dinitrobenzylidene)-2-nitroaniline*, $(O_2N)_2C_6H_3.CH{:}N.C_6H_4.NO_2$; yel, light-sensitive ndls

(from alc, acet or toluene), mp 174.5°; easily sol in chlf, benz or acet; diffc sol in alc; insol in w; was prepd by heating 2,4-dinitrobenzaldehyde with o-nitroaniline in AcOH soln(Refs 1 & 4)
*N-(2,4-Dinitrobenzylidene)-3'-nitroaniline,* yel light-sensitive ndls(from alc, acet or toluene), mp 138°; easily sol in chlf, benz, alc, acet or AcOH; insol in w; was prepd by heating 2,4-dinitrobenzaldehyde with m-nitroaniline in 95% alc(Refs 2 & 4)
*N-(2,4-Dinitrobenzylidene)-4'-nitroaniline*, yel, light-sens ndls(from alc), mp 169.5°; very sol in chlf, benz, alc, AcOH or acet; insol in w; was prepd by heating 2,4-benzaldehyde with p-nitroaniline in alc soln(Refs 3 & 4)
*Refs*: 1)Beil **12**, [370] 2)Beil **12**, [379] 3)Beil **12**, [388] 4)A.Lowy & T.B.Downey, JACS **43**, 347(1921)
**Tetranitrobenzylideneaniline**, $C_{13}H_7N_5O_8$; mw 361.23, N 19.39%, OB to $CO_2$ -95.2%. The following isomer is described in the literature:
*N-(2,4,6-Trinitrobenzylidene)-3-nitroaniline*, $(O_2N)_3C_6H_2.CH{:}N.C_6H_4.NO_2$; yel crysts, mp 161-2°; was prepd by interaction of 2,4,6-trinitrobenzaldehyde with m-nitroaniline in cold AcOH. Its expl props were not detd
*Refs*: 1)Beil- not found 2)S.Secareanu,BullFr **51**,591(1932) & CA **26**,5081(1932) 3)S.Secareanu & I.Lupus,JPraktChem **140**,94(1934) & CA **28**, 5445(1934)
*Pentanitro*-$C_{13}H_6N_6O_{10}$ and *Hexanitro*-$C_{13}H_5N_7O_{12}$, *Derivatives* were not found in Beil or in CA thru 1956

**(N-Benzylidene-N'-azidomercapto)-hydrazine.** See 2-Benzylidene-thiocarbazoyl Azide

**Benzylideneazine.** See Benzaldehydeazine

**2-Benzylidene-thio-carbazoyl Azide; Benzalthio-carbazinic Acid Azide or (N-Benzylidene-N'-azidomercapto)-hydrazine** (called Benzalthiocarbazinsäureazid by Stollé), $C_6H_5.CH{:}N.NH.C(:S).N_3$; mw 205.30, N 34.12%; pale yel flakes, mp 173°, followed by an expl; sol in hot alc or hot AcOH; insol in w; was prepd by shaking for 8 hrs a mixt of dithiocarbazinic acid hydrazide, Na azide & Pb oxide in alc medium
*Refs*: 1)Beil- not found 2)R.Stollé & E.Gaertner, JPraktChem **132**,225(1931) & CA **26**,1608(1932)

**Benzylidyneoxyhydroxytetrazotic Acid.** See Phenyloxyhydroxytetrazotic Acid

**Benzylidyneoxytetrazotic Acid.** See Phenyloxytetrazotic Acid

### Benzylmalonic Acid and Derivatives

*Benzylmalonic Acid* [called 1-Phenyl-äthan-dicarbonsäure-(1.1) in Ger], $C_6H_5.CH_2.CH(COOH)_2$; mw 194.18, crysts(from eth), mp 121°, dec ca 180°. Other props & prepn are given in Beil **9**,868,(381) & [619]
**p-Nitrobenzylmalonazidic Acid** (called p-Nitrobenzyl-malonazidsäure in Ger), $O_2N.C_6H_4.CH_2.CH(CO.N_3).COOH$; mw 264.20, N 21.21%; fine ndls(from eth), expl when heated on a metallic spatula in a flame; was prepd by treating p-nitrobenzylmalonhydrazidic acid with aq Na nitrite as indicated in Ref 2. Its soln in eth is stable at RT
*Refs*: 1)Beil- not found 2)T.Curtius & W.Mühlhäusser,JPraktChem **125**,296(1930) & CA **24**,3216-17(1930)
**Benzylmalondiazide** (called Benzylmalonsäure-diazid in Ger), $C_6H_5.CH_2.CH(CO.N_3)_2$; mw 244.21, N 34.42%; yel oil, expl on heating; sol in alc or eth; insol in w; was prepd by treating benzylmalondihydrazide in HCl with concd aq soln of Na nitrite as indicated in Ref 2)
*Refs*: 1)Beil **9**,(382) 2)T.Curtius et al,JPrakt Chem **94**,327(1916-17) & CA **14**,1670(1920)
*Mononitrobenzylmalonic Acid*, $C_{10}H_9NO_6$; mw 239.18, N 5.86%. Its three isomers; 2-Nitro-, 3-Nitro- and 4-Nitro-, none of them expl, are described in the literature
*Refs*: 1)Beil **9**,871 & [621-624] 2)J.W.Baker & A.Eccles,JCS **1927**,2127 & CA **22**,65(1928) 3)J.M.Gulland et al,JCS **1929**,1670 & CA **23**,5186 (1929)
*Dinitrobenzylmalonic Acid*, $C_{10}H_8N_2O_8$ and *Trinitrobenzylmalonic Acid*, $C_{10}H_7N_3O_{10}$ were not found in Beil or in CA thru 1956

**Benzyl Nitrate.** See under Benzyl Alcohol

**Benzyl Nitrite.** See under Benzyl Alcohol

### Benzyloxamic Acid and Derivatives

*Benzyloxamic Acid* (called Oxalsäuremonobenzylamid or Benzyloxamidsäure in Ger), $C_6H_5.CH_2.NH.CO.COOH$; mw 79.17, N 7.82%; plates(from w). mp 128-9°; other props & prepn are in Beil **12**,1047-8
**Benzyloxaminyl Azide**, $C_6H_5.CH_2.NH.OC.CO.N_3$; mw 204.19, N 27.44%; lfts, expl at 80-90°; sol in acet or chlf; diffc sol in eth or benz; was prepd

by treating benzyloxaminyl hydrazide in HCl with Na nitrite as described in Ref 2
*Refs*: 1)Beil- not found 2)T.Curtius & K.Raschig, JPraktChem **125**,484-5(1930) & CA **24**,3231(1930)
*Mononitro-*, $C_9H_8N_2O_5$, *Dinitro-*, $C_9H_7N_3O_7$ and *Trinitro-* $C_9H_6N_4O_9$ *Derivatives* were not found in Beil or in CA thru 1956

**Benzylperacetate.** See Acetylbenzylperoxide, Vol 1,p A55-L

**Benzyl Perchlorate,** $C_6H_5.CH_2.ClO_4$. Burton & Praill(Ref 2) mentioned that they prepd this compd by the action of $AgClO_4$ on benzyl bromide in benz with or w/o added nitromethane. No props are given. The same compd is mentioned in Ref 3, where some reactions of benzylperchlorate are discussed
*Refs*: 1)Beil- not found 2)H.Burton & P.F.G. Praill,Chem&Ind **1951**,939 & CA **46**,6077(1952) 3)Ibid,JCS **1953**, 827 & CA **48**,758(1954)

### Benzylphenyl Ether and Derivatives

*Benzylphenyl Ether or Phenylbenzyl Ether* (Called Phenylbenzyläther in Ger), $C_6H_5.CH_2.O.C_6H_5$; it is described in Beil **6**,432,(220) & [411]
*Mononitrobenzylphenyl Ether,* $O_2N.C_6H_4.CH_2.O.C_6H_5$; mw 231.24; N 6.06%. Two isomers are described in Beil **6**,449, 450, (223) & [425]
*Benzylmononitrophenyl Ether,* $C_6H_5.CH_2.O.C_6H_4.NO_2$; mw 231.24, M 6.06%. Three isomers are described in Beil **6**,433,(220) & [412]
*Mononitrobenzyl-mononitrophenyl Ether,* $O_2N.C_6H_4.CH_2.O.C_6H_4.NO_2$; mw 274.23, N 10.22%. Three isomers are described in Beil **6**,449,451 & [425]
*Benzyl-dinitrophenyl Ether,* $C_6H_5.CH_2.O.C_6H_3(NO_2)_2$; mw 274.23, N 10.22%. Two isomers are described in Beil **6**,433 & [412]
**Mononitrobenzyl-dinitrophenyl Ether,** $O_2N.C_6H_4.CH_2.O.C_6H_3(NO_2)_2$; mw 319.23, N 13.16%. Two isomers are described in the literature: *4-Nitrobenzyl-2,4-dinitrophenyl Ether,* Orn-yel ndls (from benz), mp 198-201°(Ref 2) and *4-Nitrobenzyl-2,6-dinitrophenyl Ether,* ndls(from benz), mp 137°(Ref 1). Other props and methods of prepn are given in the Refs
*Refs*: 1)Beil **6**,451 2)Beil **6**,451 & [425]
**2,4-Dinitrobenzyl-4-nitrophenyl Ether,** $(O_2N)_2C_6H_3.CH_2.O.C_6H_4.NO_2$; mw 319.23, N 13.16%; almost col ndls(from NB), mp 202-204°; readily sol in warm toluene; sl sol in acet or glac AcOH; insol in w or alc; other props and method of prepn are given in the Ref. Its expl props were not detd
*Refs*: Beil **6**,[426]

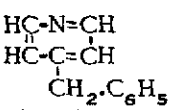
**Benzyl-2,4,6-trinitrophenyl Ether** [called Benzylpikrat; Pikrinsäurebenzyl-äther or (2.4.6-Trinitro-phenyl)-benzyl-äther in Ger],
$C_6H_5.CH_2.O.C_6H_2(NO_2)_3$; mw 319.23, N 13.16%; almost col prisms(from benz), or pltlts(from alc), mp 145-147°; diffc sol in alc or eth; other props and method of prepn are given in Ref. Its expl props were not detd
*Ref*: Beil **6**,433
**4-Nitrobenzyl-2,4,6-Trinitrophenyl Ether,** $O_2N-C_6H_4.CH_2.O.C_6H_2(NO_2)_3$; mw 364.23, N 15.38%; almost col crysts(from glac AcOH), mp 108°; v sl sol in cold alc or eth; diffc sol in cold benz or glac AcOH; was prepd by heating, on a w bath, the Ag salt of PA and p-nitrobenzyliodide; other props are given in the Refs. Its expl props were not detd
*Refs*: 1)Beil **6**,451 2)G.Kumpf,Ber **17**,1075(1884) & JCS **46** II,1005(1884)
**Pentanitro Derivatives of Benzylphenyl Ether,** $C_{13}H_7N_5O_{11}$, mw 409.23, N 17.12%. Two compds, presumably: *2,4-Dinitrobenzyl-2,4,6-trinitrophenyl Ether,* $(O_2N)_2C_6H_3.CH_2.O.C_6H_2(NO_2)_3$(?) and *2,4,6-Trinitrobenzyl-2,4-dinitrophenyl Ether,* $(O_2N)_3C_6H_2.CH_2.O.C_6H_3(NO_2)_2$(?) were reported prepd by nitration of either 4-nitrobenzyl-2,4-dinitrophenyl ether(mp 207-8°) or 2-nitrobenzyl-2,4-dinitrophenyl ether(mp 188°), using mixed nitric-sulfuric acids. A product of mp 146°(dec), but not further identified, was obtd on recrystn from chlf. Attempts to prep a hexanitro deriv led to formation of decompn products
*Refs*: 1)Beil- not found 2)H.Ryan & J.Keane,Sci-ProcRoyDublinSoc **17**,287(1924) & CA **18**,1654 (1924)
*Hexanitro Derivative of Benzylphenyl Ether,* $C_{13}H_6N_6O_{13}$, was not found in Beil or in CA thru 1956

**Benzyl Picrate.** See Benzyl-2,4,6-trinitrophenyl Ether under Benzylphenyl Ether

### Benzylpyridine and Derivatives

*Benzylpyridine* (called 2-, 3- or 4-Benzyl-pyridin in Ger), $C_{12}H_{11}N$; mw 169.22, N 8.28%. This compd exists in 3 isomeric forms:

| | |
|---|---|
| HC-N=C.$CH_2$.$C_6H_5$ | HC-N=CH |
| HC-CH=CH | HC-CH=C.$CH_2$.$C_6H_5$ |
| 2(or $\alpha$)-Benzylpyridine | 3(or $\beta$)-Deriv |



4(or γ)-Deriv

The *2-Deriv* is a citron-like liq, bp 276° at 742mm, d 1.054 at 20°(Ref 1); *3-Deriv*, ndls, mp 34°, bp 287-8° at 760mm(Ref 2) and *4-Deriv*, liq, bp 287° at 742mm, d 1.061 at 20°(Ref 3). All derivs form cryst, colored salts and addn compds, such as picrate, nitrate, etc. Their props and prepn are given in the Refs

*Refs*: 1)Beil **20**,425,(158) & [270] 2)Beil **20**, 426 & [272] 3)Beil **20**,426,(158) & [272] 4)C.H.Hands & F.R.Whitt,JSCI **66**,407-9(1947) & CA **42**,3754(1948)(Describes a pilot plant for the prepn of mixed benzylpyridine isomers)

*Mononitrobenzylpyridine*, $O_2N.C_6H_4.CH_2.C_5H_4N$; mw 214.22, N 13.08%. The following isomers are described in the literature: *2-(2-Nitrobenzyl)-pyridine*, yel oil, bp 160-170° at 0.4mm(Ref 5); *2-(3-Nitrobenzyl)-pyridine*, yel oil; isolated as the *picrate*, mp 157-8°(Ref 4); *2-(4-Nitrobenzyl) -pyridine*, pale yel ndls(from dil alc), mp 81°(Refs 1,2,4 & 5); *3-(4-Nitrobenzyl)-pyridine*, col prisms (from alc), mp 88°(Refs 1 & 2); *4-(2-Nitrobenzyl) -pyridine*, pale yel oil, bp 160-170° at 0.4 to 0.6 mm(Ref 5); *4-(3-Nitrobenzyl)-pyridine*, obtd with other isomers, but isolated as the *picrate*, mp 156-7°(Refs 1 & 2); and *4-(4-Nitrobenzyl)-pyridine*, prisms(from dil alc), mp 74°(Refs 1,2,3 & 5). All mononitro derivs form salts and addn compds, such as hydrochloride, nitrate, picrate, etc. Their other props and methods of prepn are given in the Refs

*Refs*: 1)Beil **20**,[271,272] 2)F.Bryans & F.L. Pyman,JCS **1929**,551-2 3)C.H.Hands & F.R. Whitt,JSCI **66**,407(1947) & CA **42**,3754(1948) 4)K.Schofield,JCS **1949**,2411 & CA **44**,2966(1950) 5)A.J.Nunn & K.Schofield,JCS **1952**,586-8 & CA **46**,9565-6(1952)

**Dinitrobenzylpyridine**, $(O_2N)_2C_6H_3.CH_2.C_5H_4N$; mw 259.22, N 16.21%. Two isomers are described in the literature: *2-(2,4-Dinitrobenzyl)-pyridine*, yel prisms(from alc), becomes blue to violet on exposure to light but turns yel again on storage in the dark or in soln, mp 91-3°(Refs 1,3 & 4); and *4-(2,4-Dinitrobenzyl)-pyridine*, yel prisms (from alc), mp 80-81°(Ref 1 & 2). Both isomers form salts and addn compds, such as the *picrates*. Other props and method of prepn are given in the Refs

*Refs*: 1)Beil **20**[271,273] 2)A.E.Tschitschibabin (A.E.Chichibabin) et al,Ber **58**,1587(1925) 3)K. Schofield,JCS **1949**,2411 & CA **44**,2966(1950) 4)A.J.Nunn & K.Schofield,JCS **1952**,587-8 & CA **46**,9565-6(1952)

*Trinitrobenzylpyridine*, $C_{12}H_8N_4O_6$- not found in Beil or in CA thru 1956

**1-(2,4,6-Trinitrobenzyl)pyridinium Azide**, $[(O_2N)_3C_6H_2.CH_2.C_5H_4N].HN_3$; mw 347.25, N 28.24%; orn-red polyhedra with brn streaks, mp 99°(dec); was prepd by adding solid Na azide to a concd aq soln of trinitrobenzyl pyridinium bromide. Its expl props were not investigated. The *Nitrite salt*, $[(O_2N)_3C_6H_2.CH_2.C_5H_4N].HNO_2$; mw 351.23, N 19.94%; yel-red plates, turning very dk-red after long exposure to light, mp 88°(dec), was also prepd, but its expl props were not investigated

*Refs*: 1)Beil- not found 2)F.Kröhnke,ChemBer **88**,859-60(1955) & CA **50**,4960(1956)

### Benzylsuccinic Acid and Derivatives

*Benzylsuccinic Acid*(called Benzylbernsteinsäure; 3-Phenyl-propan-dicarbonsäure-(1.2) or γ -Phenyl-brenzweinsäure in Ger), $C_6H_5.CH_2.CH(COOH).CH_2.COOH$; mw 208.21; ndls or lfts (from w), mp 160-1°. Other props & prepn are given in Beil **9**,877(384) & [628]

**Benzylsuccinyl Diazide**(called Benzyl-bernsteinsäure-diazid in Ger), $C_6H_5.CH_2.CH(CO.N_3).CH_2.CO.N_3$; mw 258.24, N 32.55%; lt yel oil(from eth), expl on heating in a flame; was prepd from benzylsuccinyldihydrazide, Na nitrite and dil HCl as described in Ref 2

*Refs*: 1)Beil- not found 2)T.Curtius & W.Sandhaas,JPraktChem **125**,105(1930) & CA **24**,3231 (1930)

*Mononitro*-$C_{11}H_{11}NO_6$, *Dinitro*-$C_{11}H_{10}N_2O_8$ and *Trinitro*-$C_{11}H_9N_3O_{10}$-*Benzylsuccinic Acids* were not found in Beil or in CA thru 1956

### Benzyltoluidine and Derivatives

*Benzyltoluidine*(called Tolyl-benzylamin or Methyl -phenyl-benzylamin in Ger), $C_6H_5.CH_2.NH.C_6H_4.CH_3$; mw 197.27, N 7.10%. Three isomers are listed in Beil **12**,1033,(452) & [551,552]. Detailed description of their prepn is given in OrgSynth **21**,108-9(1941)

*Nitrosobenzyltoluidine*, $C_{14}H_{14}N_2O$; mw 210.27, N 13.33%. Four isomers are described in Beil **12**, 1033,1034,1071 & [573]

*Mononitrobenzyltoluidine*, $C_{14}H_{14}N_2O_2$; mw 226.27, N 12.38%. Three isomers are described in Beil **12**,1033,1078 & [577]

*Dinitrobenzyltoluidine*,$C_{14}H_{13}N_3O_4$; mw 287.27, N 14.63%. Three isomers are described in Beil **12**,1034,1089 & [552]

**Trinitrobenzyltoluidine,** $C_{14}H_{12}N_4O_6$; mw 332.27, N 16.86%. Two isomers: *(2,4,6-Trinitrobenzyl)-o-toluidine*, orn-yel ndls, mp 140° and *(2,4,6-Trinitrobenzyl)-p-toluidine*, brn ndls, mp 122° are described in Beil **12**,(468)

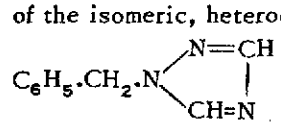
**Tetranitrobenzyltoluidine,** $C_{14}H_{11}N_5O_8$; mw 377.27, N 18.56%, OB to $CO_2$ -108.1%.
The following isomer is described in the literature: *N-(3'-Nitrobenzyl)-N,2,6-trinitro-p-toluidine or 3-Nitrobenzyl-(4-methyl-2,6-dinitrophenyl)-nitramine,* $O_2N.C_6H_4.CH_2.N(NO_2).C_6H_2(NO_2)_2.CH_3$; col crysts, mp 167°(evoln of gas or expln); easily sol in acet or boiling AcOH; less sol in benz; sl sol in alc or chlf; v sl sol in eth or petr eth; was prepd by nitration of 3-nitrobenzyl-4-methylaniline with nitric acid(d 1.46)(Ref 2,pp 1061 & 1066)

**Pentanitrobenzyltoluidine,** $C_{14}H_{10}N_6O_{10}$; mw 422.27, N 19.90%, OB to $CO_2$ -87.1%. The following isomer is described in the literature: *N-(2',4'-Dinitrobenzyl)-N,2,6-trinitro-p-toluidine or 2',4'-Dinitrobenzyl-(4-methyl-2,6-dinitrophenyl)-nitramine,* $(O_2N)_2C_6H_3.CH_2.N(NO_2).C_6H_2(NO_2)_2.CH_3$; col crysts, mp 144°(evoln of gas or expln); v sol in acet, benz or chlf; sol in warm AcOH; less sol in alc; v sl sol in eth or petr eth; was prepd by nitration of 4'-nitrobenzyl-(4-methyl-2,6-dinitrophenyl)-nitramine with mixed nitric-sulfuric acid(Ref 2,p 1060)

*Refs:* 1)Beil- not found 2)P.van den Berg,Rec **55**,1060,1061,1066(1936) & CA **31**,2179(1937)

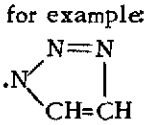
### Benzyltriazole and Derivatives

*Benzyltriazole,* $C_9H_9N_3$; mw 159.19, N 26.40%. This compd presumably exists as benzyl derivs of the isomeric, heterocyclic triazole, for example:



1-Benzyl-sym(or 1,2,4)-triazole

and



1-Benzyl-vic(or 1,2,3)-triazole

Only the 1-benzyl-vic-triazole, crysts(from eth at -20°), mp 61°, appears to have been prepd and reported in the literature. Curtius & Raschig(Ref 2) prepd 1-benzyl-vic-triazole by the reaction of benzyl azide with the methyl ester of acetylenedicarboxylic acid, followed by sapon and decarboxylation. Wiley et al(Ref 3) prepd the compd directly and in better yield from acetylenedicarboxylic acid, followed by decarboxylation to 1-benzyl-vic-triazole(77% yield)

Although not reported to have been prepd, the 1-benzyl-sym-triazole may be considered the parent compd of some nitro derivs which have been prepd

*Refs* 1)Beil- not found 2)T.Curtius & K Raschig,JPraktChem **125**,466(1930) 3)R.H.Wiley et al,JOC **21**,191(1956) & CA **50**,15517(1956)

*Azido-* $C_9H_8N_6$ and *Diazido-* $C_9H_7N_9$ *derivs* were not found in Beil or in CA thru 1956

*Mononitro-* $C_9H_8N_4O_2$, *Dinitro,* $C_9H_7N_5O_4$ and *Trinitro-benzyltriazoles* $C_9H_6N_6O_6$, were not found in Beil or in CA thru 1956

**1-(4'-Nitrobenzyl)-3,5-dinitro-sym-triazole,** was prepd and described by N.K.Sundholm et al in Conf Progress Rpt of Naugatuck Chem Div of US Rubber Co, 15 Oct 1949-15 Dec 1949(NORD 10121),p 7

**Berclavite B.** An aluminized expl: AN 79.5, Al 5, NG 5, cellulose 5, DNT 5 & NC(12%N) 0.5%. It has been claimed that its power as measured by *CUP* is 125(PA=100)(See Vol 1,p A IX)
*Ref:* L.Médard,MAF **22**,596(1948

**Berdanka**(Berdan rifle). A cal 10.7mm, one-shot breech-loading rifle with a bolt system magazine developed in the 1870's by the Amer General Berdan and adopted in a modified form by the Rus Govt for the Armed Forces. The weapon proved to be so good that it was used for many years. Although it was replaced in the regular Army ca 1891 by a 5-cartridge magazine firearm developed by Mossin & Nagan, the so-called *trëkhlineynaya vintovka*(three-line rifle cal 7.62mm), the Berdanka was used by irregular troops(opolchentsy) as late as WWI and perhaps later. The cavalry version of Berdanka was used for training in military schools
*Refs:* 1)W.W.Greener,"The Gun and Its Development",London(1885),135 2)W.H.B.Smith,"NRA Book of Small Arms",Harrisburg,Pa, **2**(1952),345 3)Dr M.M.Kostevitch,Buenos Aires,Argentina; private communication(1954)

**Berg(Explosive),** also known as **Nitrolkrut,** was patented in 1876 in Sweden. It was prepd by blending 100 parts of a mixt of NG 94-99 plus NC 1-6% with 50-150 ps of nitrates(of K,Na or Amm) plus charcoal. Nitrated hydrocarbons might be used instead of NG
*Ref:* Daniel(1902),560

**Bergé(Explosive).** An expl mixt suitable for blasting: K chlorate 61.0, K bichromate 6.1, sugar (or charcoal) 27.4 & yel wax 5.5%
*Ref:* Dr M.M.Kostevitch, Buenos Aires,Arg; private communication(1954)

**Bergenström (Explosive).** known also as **Salite,** was patented in 1878. It consisted of NG 65 & urea nitrate 35%
*Ref*: Daniel(1902),699

**Berger** (Explosive). An ammonal-type expl, proposed ca 1905 as a filler for projs: AN 86, stearic acid 8 & Al 6%
*Ref*: Dr M.M.Kostevitch, Buenos Aires; private communication(1954)

**Berger Mixtures** are smoke-producing compns, introduced by the French, consisting of finely divided Zn in $CCl_4$ mixed with other ingredients. On ignition of such mixtures, Zn decomposes the $CCl_4$ with the formation of $ZnCl_2$ as a vapor. On contact with cool air, the vapor condenses and on combining with moisture a white cloud is formed(Ref 1). The compn of the Fr Berger pyrotechnic mixt listed by Pepin Lehalleur(Ref 2) is: Zn dust 15, ZnO 20, Ca silicide 15, tetrachloroethane 40, & Na chlorate 10%

The so-called *American Mixture*, listed by Marshall(Ref 1), consisted of Zn dust 34.6, $CCl_4$ 40.8, NaCl 9.3, Amm chloride 7.0 & Mg carbonate 8.3% and was used in the form of candles. It was cheaper but less effective than smoke-producing mixts based on phosphorus

Another mixt which contained neither Zn nor $CCl_4$ was also called *Berger Mixture*. Its compn was: pitch 29.2, saltpeter 47.4, borax 10.6, Ca carbonate 4.9, sand 4.0 & sulfur 3.9%. It was cheaper but less effective than the above American Mixture
*Refs*: 1)Marshall **3**(1932,199 2)Pepin Lehalleur (1935),470

**Bergès, Corbin et Cie à Chedde.** The name of the French firm who manufd *Cheddites* for many years

**Bergmann, Emil** (1857-1922). A Ger scientist specializing in expls and proplnts. In collaboration with Junk, he developed a test for stability of NC & proplnts. Was director of the Chemisch-technische Reichsanstalt
*Ref*: H.Kast,SS **18**,37-9(1924)(Obituary and biography)

**Bergmann Explosives,** patented in Germany beginning 1893, existed in several modifications. The original compn was prepd by melting together 8.3 parts of DNPh (or DNCrs) & 4.2 ps of aniline (toluidine or naphthylamine) and adding this melt gradually to a double-bottom vessel provided with a stirrer and contg 87.5 ps of finely pulverized AN, preheated to 80°. The resulting mixt was cartridged while still hot

In later compns, the mixt DNPh-aniline was replaced by mixts of aromatic nomo-and di-nitro compds
*Ref*: Daniel(1902),64

**Bergmann-Junk Test** (B-J Test). The original test, designed by Bergmann & Junk(Ref 1) for testing stability of NC and propellants, was modified during WWI by Mayrhofer(Ref 2) and later by Meerscheid-Hüllessem(Ref 4). The test has been widely used in Europe and to some extent in the US

Following is a brief description of the procedure as used for NC:
a) Weigh at least two 2.02g samples of NC in tared weighing bottles(provided with ground glass stoppers) and dry them at 100±1° for 80 mins with stoppers open
*Note*: In testing double-base proplnts same size samples as above can be used, while for single -base proplnts samples as large as 5g are sometimes required
b) Stopper the bottles, cool in a desiccator and reweigh
c) Transfer the contents of each bottle as quickly as possible(to avoid absorption of moisture from the air) to special cylindrical glass vessels (see Ref 1), each provided with a ground-glass neck which can be closed with a stopper attached to an absorption tube contg ca 25ml of freshly distd water which serves to absorb the fumes of nitrogen oxide formed
d) Heat(behind a light barricade) the vessels with attached absorption tubes in a special bath which is provided with wells(to accomodate the cylindrical vessels). The bath is filled with a mixt of glycerin-water(4:1), which boils at 132±0.2°
*Note:* The B-J- apparatus was manufd in England by Callencamp,London. The bath was similar to the one described in ASTM Standards,Part 11 (1946),Test D301-33, p 1714
e) After 2 hours heating, remove each vessel and leave it on a rack to cool. As the ensemble continues to cool, the water is drawn from the absorption tube to the cylindrical vessel thus wetting the NC and dissolving any nitrogen oxides absorbed by the NC as well as any accumulation on the walls of the vessel
f) Remove each absorption tube and rinse it with distd w into the cylindrical vessel until the 50ml

mark is nearly reached
g)Stopper the vessel(with a glass stopper), shake it until all NC is dislodged from the bottom and add distd w to the 50ml mark
h)Filter the contents into a glass-stoppered bottle and det nitrogen oxides as NO by the Schultze-Tiemann method, which is described in Ref 6,pp 218-20 and in Ref 7,pp 21-5. The vol of NO(in $cm^3$) per lg of sample may be called *Bergmann Value* or *Bergmann Number*(Indice de Bergmann, in Fr). It must not exceed 5.0ml/lg for NC of 13% N and 4.0ml/lg for NC of 12%N. The values for expls are much smaller(see Bergmann Number)

By multiplying the ml's of NO by 1.34, the values in mg's are obtained. Wiggam & Goodyear (Ref 2a) stated that values in excess of 6.5mg of NO per lg of a propellant indicate instability
*Note*: Instead of using the Schultze-Tiemann method, a simple titration of the above soln(see h) with alkali might suffice. This titration gives the amts of nitric and nitrous acids which form as the result of the reaction:

$$2NO_2 + H_2O \rightarrow HNO_3 + HNO_2$$

and from this, total amt of N and corresponding NO can be calcd
*Refs*: 1)E.Bergmann & A.Junk,ZAngChem **17**, 982,1018 & 1074(1904) and JSCI **23**,953(1904) 2)F.Mayrhofer,SS **13**,425 & 448(1918)(Modification of B-J test) 2a)D.Wiggam & E.Goodyear, IEC,AnalEd **4**,74(1932) 3)Stettbacher(1933), 142-3 4)V.Meerscheidt-Hüllessem,SS **29**,192-4 (1934); **30**,75(1935) & **31**,362-3(1936)(Modification of B-J test) 5)Reilly(1938),83-4 6)Kast-Metz(1944),218-20 & 312 7)PATR **1401**,Rev 1 (1950),19-25 8)P.Aubertein,MP **41**,117(1959)(A brief description of the B-J test, called *"épreuve de Bergmann-Yunk"* in France)

**Bergmann Number**(BN)(indice de Bergmann, in Fr) is the amt of NO(in $cm^3$) evolved per 1g of sample(such as 5g) heated at 132° for 2 hrs in the Bergmann-Junk apparatus(Ref 2). The Fr test ("épreuve de Bergmann-Yunk") is described as the "Méthode Réglementaire,Annexe n°1)", which is not available at PicArsn

Bourjol(Ref 1) & Aubertein(Ref 2) detd recently the BN for several HE's, particularly PETN and its mixts with nitrocompds

Following are some BN's for PETN and its mixts with other expls, as detd by Bourjol(Ref 1)

PETN(alone) 0.01, PETN+0.1% DNT 0.08, PETN+1% DNT 0.85, PETN+0.1% TNT 0.09, PETN+1% TNT 0.70, PETN+0.1% Tetryl 0.05, PETN+1% Tetryl 0.50, PETN+0.1% RDX 0.03, PETN+1% RDX 0.07, PETN+0.1% Nitropropane 0.01 and PETN+1% Nitropropane 0.04

Aubertein(Ref 2,p 120) gives BN for PETN equal to 0.03
*Refs*: 1)G.Bourjol,MP **35**,83-7(1935) & CA **50** 1507(1956) 2)P.Aubertein,MP **41**, 117 & 120 (1959) 3)P.Aubertein,MP **42**,39-46(1960)(BN of PETN)

**Bergmann's Powder.** Composed of a mixt of K chlorate 50, Mn dioxide(pyrolusite) 5 & bran+ woodflour 45%
*Ref*: CondChemDict(1942),288(not found in later editions)

**Berg-Roburite Explosive.** A mixt of DNB & AN with or without phenol
*Ref*: Daniel(1902),64

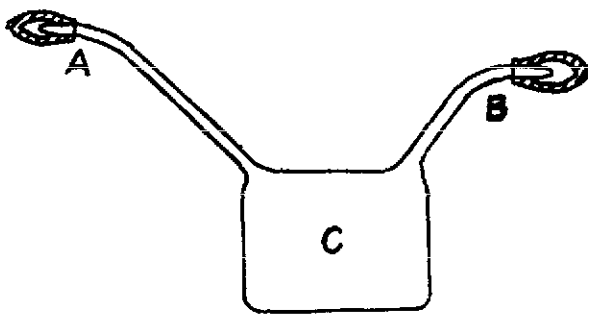
**Berkhout Stability Test**, designed in the artillery laboratory at Hembrug,Holland, consists in heating samples of NC or proplnts in weighing bottles at 95°, 105° or 110° and noting the loss of wt in a definite period(such as 72 hrs), as well as the time required for evoln of red fumes. The heating is conducted in a specially designed thermostatically controlled oven. Two models of such ovens are described in Ref 1
(Compare with Jacqué Test and with Sy Test)
*Refs*: 1)J.D.Berkhout,SS **17**,33-4(1922) & CA **16**, 2602(1922) 2)Reilly(1938),85

**Berl, Ernst**(born in Austria 1877, died in US 1946). An Austrian-American scientist, an authority on expls, cellulose, NC, NS, acids, etc. Inventor of "Berl saddles",(qv) and Berl pipette(qv). Co-author with Dr Georg Lunge of the "Chemisch-technische Untersuchungsmethoden", series of books published in Germany after WWI
*Refs*: 1)M.Isler,Helv **29**,957-73(1946) (Obituary & biography with portrait) 2)K.Winnaker,Chem-IngTech **23**,105-6(1951) & CA **45**,4977(1951)(A biographical sketch)

**Berl & Kunze Semimicro Analytical Determination of Stability of NC** is described in Angew Chem **45**,669-70(1932) & Chim & Ind(Paris) **29**, 607D(1933)

**Berl Pipette** is a vessel, invented by E.Berl and made by Mr Donat of the USBurMines, for weighing out small quantities of acids or other liquids. It was tried during WWII in the lab of Keystone Ordnance Works, Meadville,Pa and found to be more convenient to use than the Lunge pipette, especially for weighing semi

-mixed and mono-waste acids used in manuf of TNT




*Procedure:* a) Clean the pipette by washing it first with cleaning soln(K or Na bichromate +concd sulfuric acid),then with water and finally with a few ml of acetone. Dry by passing compressed air through it b)For filling the pipette, remove both ground glass caps and plunge the tip of the long tube A into the bottle contg the liq sample c)Attach to the end of tube B a short piece of rubber tubing connected at the other end to a rubber suction bulb and draw liq into reservoir C until it is about half full d)Remove the tip of A from the liq and disconnect the suction bulb e)Wipe the tip of A with tissue paper and replace caps on A & B. Wipe the outside of pipette and weigh the ensemble to 0.1mg f)For sampling the acid(or other liq) with the pipette, remove both caps and, by tipping the pipette toward A, let the acid drip slowly through A into an Erlenmeyer flask contg distd w g)Straighten the pipette and touch tip of A to a dry spot inside neck of flask h)Replace the caps on A and B and reweigh the ensemble

*Ref*: Clift & Fedoroff,vol **3**(1944), Chapter 1,p 1.

**Berl Saddles.** Pieces of chemical porcelain, chemical stoneware or carbon in the shape of saddles, used for packing absorption towers or distn columns. They are manufd under trade name "Intalox Saddles" by the US Stoneware Co, Akron 9, Ohio

**Bernadou, John B** (1858-1908). According to Ref, Bernadou was a "French and Russian scholar and Naval Attaché (US) at St Petersbourg". While in Russia he learned about Mendeléev's smokeless proplt made by gelatinization of *pyrocollodion* (NC with N=12.44%) and decided, on his return to the US, to introduce it to the Navy. He raised the N content of NC to ca 12.6% and named it *pyrocellulose*. By gelatinizing this material with a volatile solvent, a single-base proplnt was manufd at the Newport Torpedo Station, where Bernadou was in charge of the smokeless proplnt factory. The same proplnt was adopted a few years later by the US Army. This proplnt, with minor modifications, is still in use

Bernadou was the author of a book entitled "Smokeless Powder,Nitrocellulose and Theory of Cellulose Molecules", Wiley,NY(1st edition 1901 and 2nd ed 1917) and he translated from Rus the book of Brynk on Ballistics

*Ref*: Van Gelder & Schlatter(1927),812-21

**Bernouilli,Daniel** (1700-1782). A French mathematician who, in his "Hydrodynamics", introduced a concept of elastic gas expansion and showed how, by taking into account this expansion, it is possible to calculate the travel of a shot in the gun barrel

*Ref*: M.Serebriakov,"Interior Ballistics",Moscow (1949),translated by Dr V.A.Nekrasoff, Catholic Univ of America, Contract NOrd 10,260(1954), Washington,DC,p 22

**Bernsteinsäure.** Ger for Succinic Acid

**Berta Apparatus** is a device used in Italy for detn of impact sensitivity of expls. The test, known as *Saggio alla Berta* is mentioned in Vol 1,p XVII of this Encyclopedia under Impact Sensitivity Test. The values obtained by Berta app are similar to those obtained by the USBurMines app, with 2kg wt. Avogadro(Ref) gives the following Berta values, in cm: PETN 38, PA 60 and TNT 80

*Ref*: 1)L.Avogadro,MAF **10**, 3(1931)

**Barthelot,Marcellin** (1827-1907). A French scientist who is considered as the founder of modern thermochemistry. He developed the theory of detonation and most of the early theoretical knowledge pertaining to expls, as well as contributing to many branches of chemistry other than expls. The author of the fundamental work on expls: "Sur la Force des Matières Explosives d'après la Thermochimie", which even today is of great value although written nearly 100 years ago

*Refs*: 1)R.Scholz,SS **3**,41-2(1908)(Obituary & brief biography) 2)F.J.Moore & W.T.Hall,"A History of Chemistry", McGraw-Hill,NY(1939), 272-7 3)H.S.VanKlooster,JChemEducn **28** 359 -63(1951)(Bunsen,Berthelot and Perkin) 4)M. Delépine,JChemEducn **31**,631-4(1954)(Berthel-

ot and industry) 5)E.Farber et al,"Great Chemists", Interscience,NY(1961),675-85

**Berthelot's Characteristic Product** (Produit caractéristique de Berthelot, in Fr)(Charakteristische Produkt des Berthelot, in Ger) and **Specific Force** (Force spécifique ou théorique; Pression spécifique, in Fr)(Spezifische Kraft oder Energie, in Ger) are theoretical expressions proposed by Berthelot for characterizing some properties of explosives and propellants. The characteristic product is the expression $Q_eV_o/c$, where $Q_e$ is the heat of explosion in cal/g(or kcal/kg, $V_o$ is the specific volume of gaseous products of expln(in cc/g or liters/kg) calcd to $0^o$ & 760mm Hg, and c is the sum of the mean specific heats of the products of expln. As the value c is difficult to calculate with precision, the product $Q_eV_o$ is often used. The calcd values for $Q_eV_o$ are betw ca 100000 and ca 1300000, and it is more convenient to express these in terms of $Q_eV_o/1000$

Berthelot considered the characteristic product as a measure of the mechanical work performed by an explosion. This work, called *potentiel de l'explosif* or *action explosive* in Fr, can also be calcd from the expression $Q_eE$, where E is the mechanical equivalent of heat. This is given by Muraour(Ref 8,p 76) as 428

Another theoretical value introduced by Berthelot is the *force spécifique* (called by Sarrau *force de l'explosif*). This, designated as f, is obtained from the expression $1073V_oT/273$, where $V_o$ is the specific vol and T is the calcd *absolute temperature of explosion*

The force f supposedly represents the pressure developed by the detonation of 1kg of explosive under perfect confinement in a 1-liter vessel, provided that the gases produced obey the Boyle-Mariotte law

*Note*: Kast used the value f for calcg brisance by his formula B=fdV, where d is the density of the expl and V is the velocity of deton(see also under Brisance)

The following table gives the characteristic product, specific force, $Q_e$, $V_o$ and T values for some explosives(Ref 3,p 152)

| Explosive | $\frac{Q_eV_o}{1000}$ | $\frac{f}{1000}$ | $Q_e$ | $V_o$ | T |
|---|---|---|---|---|---|
| Blasting Gelatin(NG 93%) | 1164 | 9511 | 1640 | 710 | 3540 |
| Nitromannite (NM) | 1099 | 9508 | 1520 | 723 | 3430 |
| 75% Guhr Dynamite | 810 | 7509 | 1290 | 628 | 3160 |
| Collodion Cotton(12%N) | 711 | 7150 | 730 | 974 | 1940 |
| Black Powder | 195 | 2987 | 685 | 285 | 2770 |
| Mercury Fulminate(MF) | 129 | 4194 | 410 | 314 | 3530 |

*f as calcd from $V_o$ and T as given by Naoum(Ref 3)

Marshall(Ref 2) stated that in 1902 Bichel found experimentally that the pressures developed on expln are nearly proportional to Trauzl test values, but the values for $Q_eV_o$ do not show the same degree of correlation. However, this does not prove conclusively that Berthelot's characteristic product is without practical significance

Rinkenbach(Ref 10), using more recent $Q_e$ and $V_o$ values, recalcd the characteristic products and found that for many expls there is a good relationship betw $Q_eV_o$ and ballistic pendulum test values. This test is considered to measure the work capacity of explosives. In the following table there are given the product and test values for a number of expls

| Explosive | $\frac{Q_eV_o}{1000}$ | Ball Pend (% TNT) |
|---|---|---|
| Hydrazoic Acid | 1320 | 161 |
| Cyclotetramethylene-tetranitramine(HMX) | 1210 | 150 |
| Cyclotrimethylene-trinitramine(RDX) | 1180 | 150 |
| Cyanuric Triazide | 1124 | 145 |
| Pentaerythritol Tetranitrate(PETN) | 1094 | 145 |
| Nitroglycerin (NG) | 1062 | 140 |
| 80/20 Amatol | 911 | 130 |
| Nitrocellulose(13.3% N) | 848 | 125 |
| 50/50 Amatol | 843 | 122 |
| Hexanitrodiphenylamine(HNDPA) | 699 | 115 |
| 60% Dynamite | 730 | 114 |
| Trinitrobenzene(TNB) | 714 | 110 |
| Picric Acid(PA) | 675 | 109 |
| Trinitrotoluene(TNT) | 655 | 100 |
| 40% Dynamite | 424 | 90 |
| Ammonium Nitrate(AN) | 339 | 78 |
| 20% Dynamite | 151 | 70 |
| Lead Azide(LA) | 113 | 66 |

When plotted, the above data indicate a linear relationship in accordance with the equation:
$\%TNT = 0.0775Q_eV_o/1000 + 58.5$

*Note:* According to the "Report on Study of Pure Explosive Compounds" by A.D.Little,Inc, Part III,367,405(1950) and Part IV, 576(1952), the correlation betw the Berthelot characteristic product and ballistic mortar value is not as good as that betw equation of state($PV = nRT$) and ball mortar test value. While this latter correlation is applicable to materials contg metallic elements, this is not true with respect to the correlation betw Berthelot's product and ball mortar test value

In addition to the linear relationship betw the characteristic product and explosive power values of high explosives shown above, there is a similar relationship betw the characteristic product and ballistic potential values of proplnt compns(Ref 11). The ballistic potential value of a compn may be expressed as either specific impulse or velocity values obtained by tests in cannon. Illustrative of this are the following data

| Composition | $Q_e V_o/1000$ | Sp Imp,lb sec/lb |
|---|---|---|
| M-13 | 796 | 242 |
| Pyrocellulose | 758.5 | 231 |
| M-1 | 706 | 213 |

*Note*: Propellant **M-1** consists of NC(13.15%N) 85, DNT 10 & DBuPh 5% with added DPhA 1% & K sulfate 1%; **M-13** consists of NC(13.15%N) 57.3, NG 40.0, EtCentr 1.0, DPhA 0.20 & K sulfate 1.5% with added Pb stearate 0.15% & carbon black 0.05%

*Refs*: 1)M.Berthelot, "Explosives and Their Power", Murray, London(1892), 30-4 2)Marshall **2**(1917),467-9 3)Naoúm, NG(1928),152 4)Pascal(1930),21 & 28 5)Vennin, Burlot & Lécorché (1932),53 6)Pepin Lehalleur(1935),40-50 7)Davis(1943), 210 8)Muraour(1947),70-6 9)Stettbacher(1948),110 10)Wm.H.Rinkenbach, private communication(1960)

**Berthelot Powder.** Under this term was known a rather unstable expl compn consisting of K chlorate 80, vaseline+paraffin 10 & chalk 10%, but Berthelot denied invention of this powder

*Ref*: Daniel(1902),65

**Berthelot Theory of Detonation,** further developed by P.Vieille, may be considered as one of the most important contributions to the modern concept of detonation

Following is a brief explanation of this theory: Supposing that a homogeneous expl in the shape of a cylindrical column is detonated at one end, there is immediately created a detonation wave which is propagated through the expl. This wave is regarded by B as a recurring cycle of transferred and released energy having four phases:

*Phase 1. Transformation of mechanical to calorific energy.* A portion of the mech energy of the layer which was detond is instantly converted into calorific energy in the adjacent layer. The portion of mech energy which is not converted to heat becomes the actual vehicle through which the work is accomplished

*Phase 2. Transformation of calorific to chemical energy.* Part of the heat released in the 1st phase is consumed in the chemical decompn of the next immediate layer of expl and thus releases the potential energy of that layer. The remainder of the calorific energy will be spent in the acceleration and reinforcement of the chem action. A considerable amt of kinetic energy is developed at this stage

*Phase 3. Transformation of chemical to calorific energy.* A complete conversion of potential energy released in previous phases to kinetic energy(which is largely calorific) takes place

*Phase 4. Transformation of calorific to mechanical energy.* As result of previous actions, a considerable vol of gas is released and as the molecules of it are in an extremely active state of molecular vibration, they are manifesting energy in a mechanical form. Since all these transformations are extremely rapid and the losses due to radiation and conduction of heat are low, the efficiency of this last phase is very high

*Refs*: 1)M.Berthelot, "Explosives and Their Power", J.Murray,London(1892),88 2)Colver(1918),596-8

**Berthold der Schwarze.** A Ger monk, living in the 14th century, to whom is usually ascribed the invention of firearms using black powder as a propellant

*Refs*: 1)F.M.Feldhaus,SS **1**,413-15(1906) 2)O. Guttmann,SS **3**,218(1908) 3)Stettbacher(1933),4

**Berthollet, Claude Louis** (1748-1822). A French scientist who made numerous contributions to chemistry and the chemical industry. In the expls field, he was first to prep K chlorate(known as "Sel de Berthollet"), Fulminating Silver and Berthollet Powder

*Refs*: 1)F.J.Moore & W.T.Hall, "A History of Chemistry", McGraw-Hill,NY(1939),104-8 2)G.Darzens, BullFr **1948**,1066-8(The life and work of Berthollet) 3)E.Farber,Edit, "Great Chemists", Interscience,

NY(1961), 315-24

**Berthollet Powder.** A compn dangerous to handle: K chlorate 75, sulfur 12.5 & charcoal 12.5%
*Ref:* Daniel(1902),66

**Berthollet Salt** (Sel de Berthollet, in Fr). Potassium Chlorate

**Beryllium (Be) or Glucinum,** at wt 9.02, lt grey metal, d 1.842, mp 1284° & bp 2767°[Lange(1956)]; mp 1350° & bp 1530° (ChemRubHdb); insol in cold w & in nitric acid; sl sol in hot w with decompn; sol in HCl, dil sulfuric acid & in alks. It does not oxidize at ordinary temp but when heated in the powder form burns brilliantly in air. It does not react with steam even at a red heat. Can be prepd by the electrolysis of a fused mixt of Be chloride with Na or Amm chlorides, or of the fluoride with NaF in a nickel crucible with a carbon anode. Be was discovered ca 1797 in the form of the oxide by Vauquelin as a constituent of the mineral beryl (emerald) (Refs 1-5)

Sartorius(Ref 6) claimed that Be or its alloys added in small quantities to expl compns render more powerful expls than those contg Al, Mg or their alloys

Boehm(Ref 8) stated that, due to the high heat of combustion of Be(29000 BTU's vs ca 19000 for hydrocarbons), it is theoretically possible to use it(or its derivs) as fuels in jets and rockets. The idea must be, however, rejected due to the high cost of Be and its extreme toxicity. Latest info on toxicity of Be and its compds is given in Ref 10
*Refs:* 1)Mellor **4**(1923),204-21 2)Gmelin,Syst Nr 26(1930),1-80 3)Thorpe **6**(1943),13-15(Glucinum) 4)Kirk & Othmer **2**(1948),490-505 5)J.R.Partington, "A Textbook of Inorganic Chemistry", Macmillan, London(1950),771 6)R.Sartorius,MP **34**,217-20 (1952) 7)D.W.White,Jr & J.E.Burke, "The Metal Beryllium", AmSocMetals,Cleveland,Ohio(1955) 8)G.Boehm,Fortune,Dec 1957,p 166 9)C.E.Darwin & J.H.Buddery, "Beryllium",Academic Press,NY (1960) 10)L.B.Tepper, "Toxicity of Beryllium Compounds", Elsevier,NY(1961)

**Beryllium Acetylide.** See vol 1,p 70-R

**Beryllium Azide..** Same as Beryllium Diazide

**Beryllium Carbide.** See Vol 1,p A71-L

**Beryllium Diazide.** See Vol 1,p A524-R

**Beryllium Sulfate.** See under Sulfates. Its use in smoke-producing compns was patented by J.DeMent USP 2995526(1961),p 6

**BESA Machine Gun.** Cal 0.303 was the Brit adaptation of the Czech, cal 7.92mm ZB-53 Model 1937, developed at the Brno factory. BESA MG's were manufd by the Enfield Royal Arms Manufacturing Arsenal and the Birmingham Small Arms (BSA) plant. The word BESA is composed of B for Brno, E for Enfield and SA, the last two letters of BSA. There were also 15mm BESA guns
*Ref:* G.M.Chinn, "The Machine Gun", USPrtgOff, Wash,DC,vol 1(1951),436-40

**Beta Cellulose** refers to that portion of industrial cellulose pulps which is sol in cold NaOH of mercerizing strength(17.5-18%) but is pptd on acidification (See also Alpha-Cellulose and Gamma-Cellulose)
*Ref:* Ott,v 5,part 1(1954),12

**Beta Compounds,** such as β-Nitronaphthalene, β-Trinitrotoluene, etc, are listed alphabetically under corresponding parent compds

**Beta and Gamma-Ray Spectroscopy** is the title of a book by K.Siegbahn,Interscience,NY(1955)

**Betaine** (Trimethyl Glycine; Trimethyl Glycocoll or Trimethyl Amino-Acetic Acid), $(CH_3)_3\underline{N.CH_2.CO.O}$ or $(CH_3)_3\overset{+}{N}.CH_2.CO.\bar{O}$; mw 117.15, N 11.96%, OB to $CO_2$ -184.4%. Prisms(from alc), mp 293°(decomp); sol in w & in alc; insol in ether; occurs in plants (usually together with choline) and in some sea animals. Can be prepd by methylation of amino-acetic acid or by other methods. Betaine has been used in org synthesis to render various compds water-soluble. For instance, Girard's reagent(which is a deriv of betaine) is used to prepare water-sol derivs of insol ketones and aldehydes(Ref 2,p 510)

Betaine forms additive compds with acids and salts, some of them explosive(See below)
*Refs:* 1)Beil **4**,346,(469) & [785] 2)Kirk & Othmer **2**(1948),510

**Betaine Additive Compounds with Acids** (Explosive) can be prepd by treating betaine with an acid rich in oxygen, such as nitric, chloric or perchloric. In the case of dichromate and permanganate additives, where the acids do not exist in the free state, the corresponding K or Na salts mixed with sulfuric acid can be used for treating the betaine:
*Betaine Chlorate,* $C_5H_{11}NO_2.HClO_3$, wh monocl

crysts, mp 115° and explg at high temps; sol in w (Refs 1 & 2)

*Betaine Dichromate*, $(C_5H_{11}NO_2)_2.H_2Cr_2O_7$; red crysts, mp 226-7°, explg at higher temps(Refs 1 & 2)

*Betaine Nitrate*, $C_5H_{11}NO_2.HNO_3$; wh lustrous plates; mp 124°, exploding at higher temps; sol in w(Refs 1 & 2)

*Betaine-Nitrogen Oxide*, $C_5H_{11}NO_2.N_2O_3$; wh crysts, obtained by prolonged action of nitric acid on betaine under pressure(Ref 2)

*Betaine-Nitrogen Oxide*, $(C_5H_{11}NO_2)_5.N_2O_3$; wh crysts, obtained by passing $N_2O_3$ into an ice-cooled soln of betaine in methanol(Ref 2)

*Betaine Perchlorate*, $C_5H_{11}NO_2.HClO_4$, wh crysts, sol in w; expl(Ref 1)

*Betaine Permanganate*, $C_5H_{11}NO_2.HMnO_4$; violet rhombic crysts, explg on heating(Refs 1 & 2)

*Betaine Picrate*, $C_5H_{11}NO_2.C_6H_3N_3O_7$; lt yel crysts(from hot w), mp 180-1°; expl(Ref 1)

*Refs*: 1)Beil **4**,(470) 2)H.Stolzenberg,BritP's5736 &5737(1914); CA **9**,2313(1915)[The use of compds of betaine with acids rich in oxygen(such as chloric, nitric, perchloric, etc) as ingredients of expls compns is recommended. Eg: betaine nitrate 36, NG 25, wheat flour 38.5 & betaine 0.5%]

**Betaine Explosive Derivatives.** Pfeifer et al(Refs 1 & 2) prepd, in the course of their work on betaine and derivs, several *perchlorates* which proved to be explosive:

a) $C_{12}H_{15}NO_2.HClO_4$; wh crysts, mp 169-70°; expl on heating in open flame(Ref 1,p 1775)

b) $C_{11}H_{13}NO_2.HClO_4$; wh crysts; mp 196-7°; expl on heating in open flame(Ref 1,p 1776)

c) $[(CH_3)_3N.C_6H_4.CH{:}CCl.CO.OH]ClO_4$; wh crysts; mp ca 280°; expl when heated on a Pt spatula(Ref 1,p 1787-8)

d) $(C_{18}H_{19}N_2O_4)ClO_4$; wh crysts; decomp explosively on rapid heating in a capillary tube(Ref 2,p 44)

*Refs*: 1)P.Pfeiffer & G.Haefelin,Ber **55**,1769-88 (1922) 2)P.Pfeiffer et al, Ann **465**,20-52(1928)

**Beta-Ray Autoradiography for the Study of Metals and Minerals on Microscale** is described by A.B. Michael et al, JApplPhys **22**,1403-6(1951)

**Betatron** is an x-ray-producing apparatus consisting essentially of an electromagnet and a donut -shaped vacuum tube placed between the pole faces of the magnet. The supply of electrons is released inside the vacuum tube from a glowing filament and, under the influence of the alternating magnetic flux, spin around the tube. During this rotary movement the electrons are accelerated(by magnetic induction instead of by direct application of high potential as is done in the more conventional types of x-ray units) and when they have reached their maximum energy their orbit is slightly increased so that they strike a platinum or thoriated tungsten target and produce x-rays. The rays emerge from the "donut" in a narrow cone in the direction which the electrons are travelling at the time

The magnetic method of acceleration(first stated in general principle by J.Slepian in 1927) has extended the range of x-rays indefinitely, the only limit being the size of the machine. The first successful unit utilizing the magnetic principle was invented and constructed by Dr D.W.Kerst at the University of Illinois in 1940. It had a maximum energy of 2.3 mev(million electron volts). Four-, ten- and twenty-mev units soon followed. Tests with the betatron showed that the best energy for industrial radiographic use is 20 mev. Manuf of these units was soon started by the Allis Chalmers Company under the supervision of Dr Kerst. Description of this apparatus may be found in Refs 7,8 & 10. Larger and more powerful units have been or are under construction for experimental work in research laboratories

From the beginning the betatron was found to be of value as a non-destructive tool in Ordnance applications. The first of the 20 mev units was installed at Rock Island Arsenal for the purpose of inspecting heavy gun mountings. A second such unit was installed at Picatinny Arsenal following WWII. This unit has not only been used for checking the internal condition of heavy or bulky metallic items pertaining to Ordnance(up tc 20" of steel can be penetrated and it is possible to detect a difference of 1/32" in any penetrable thickness of steel), but also for checking the explosive filler of large projectiles for the presence of voids or foreign material. This has resulted in a wealth of information without destruction of materials being inspected. More recently three 24 mev betatrons have been installed in eastern and midwestern steel foundaries for inspection of armor steel castings before assembly into army tanks.

In addition to the penetrating power of the x-rays there are certain other characteristic phenomena encountered in radiography with the betatron not found with low voltage x-rays, such as: a) A relative freedom from scattered radiation. The secondary radiation will tend to retain direction which the primary radiation originally had. Hence, no blocking is necessary around an irregular object or be-

hind the cassette b) A near absolute sensitivity. This means the size of the minimum detectable flaw with a given film technique does not depend on total thickness of the specimen being x-rayed, but is independent of the specimen thickness. Another phenomena is direct magnification up to 3X without loss of definition or detail. This is due to a combination of fine focal spot and the lack of secondary scattered radiation. These characteristics of the radiation produced by the betatron frequently extend its usefulness beyond the range of conventional x-ray units

*Note*: The section on Betatron was prepd in collaboration with Kathleen G.Sheffield, formerly of PicArsn,Dover,NJ

*Refs*: 1)J.Slepian,USP 1,645,304(1927) 2)R. Wideroe,ArkivElektrotech **21**,387(1928) 3)E.T.S. Walton,ProcCambridgePhilSoc **25**,469(1929) 4)M. Steenbeck,USP 2,103,303(1937) 5)D.W.Kerst, PhysRev **58**,841(1940); ibid **59**,110(1941) & ibid **60**,47-53(1941)(Acceleration of electrons by magnetic induction) 6)D.W.Kerst & R.Serber,Phys Rev **60**,53-8(1941)(Electronic orbits in the induction accelerator) 7)D.W.Kerst,AmJPhys **10**, No 5,219-24(1942)(The betatron) 8)D.W.Kerst,RevSciInstr **13**, No 9,387-94(1942)(A 20-million-electron-volt betatron or induction accelerator) 9)H. W.Koch,D.W.Kerst & P.Morrison,Radiology **40**,120 -6(1943)(Experimental depth dose for 5,10,15 and 20-millivolt x-rays) 9a)D.W.Kerst,OSRD **1333** or PBL **5224**(1943) 10)J.P.Girard & G.D.Adams, TransAmInstElecEngrs **65**,241-6(May 1946)(Application of the betatron to practical radiography) 11)H.Hinterberger,SBOesterAkadWiss,Abt IIa, 156, No 5-6,299 & 334(1948)(A general theory of the betatron) 12)D.W.Kerst et al,RevSciInstr **21**,462 -80(May 1950)(An 80-mev model of a 300-Mev betatron) 13)M.Hetényi,"Handbook of Experimental Stress Analysis",Wiley,NY(1950),982 14)R.Widröe , ZVerDeutIng **96**(15-16), 450-6(1954)(Verkstoffprüfung mit Betatron-Röntgenstrahlen), translated in GtBrit by Tech Info & Library Services TIL/T4575(Feb 1958)("Material Testing by Betatron")(numerous refs) 15)P.Grivet,RevGénElec **64**,239-62(1955) & CA **49**,11429(1955)(Review on theoretical principles and properties of the betatron and synchrotron) 16)USNatBurStdsHandbook No 55, "Protection Against Betatron-Synchrotron Radiations up to 100 Million Electron Volts", USDept of Commerce, Washington,DC(1955),52pp 17)Collier's Encyclopedia **7**(1957),190(Under Electron and Ion Accelerators) 18)F.Timpl,Technik(Berlin) **12**,513-18, 541-7 & 612-16(1957); CA **51**,16119(1957) & **52**, 101(1958)

**Bettanin's Explosive.** A mixt of dynamite(preferably with 60% NG) 76, K chlorate 18 & oil of pine (tar or rosin) 6%

*Ref*: F.P.Bettanin,USP 930030(1909) & CA **3**,2753 (1909)

**Bettermann's Electric Delay Detonator**, patented in 1898, may be considered as the precursor of modern delay detonators. A detailed description with schematic drawing is given in Daniel(1902), 66-7

**Bevatron** is a very powerful particle accelerator installed in 1954 at the Univ of Calif. This machine is capable of accelerating protons to an energy of 5 BEV(billion electron volts)

*Ref*: Anon,Ordnance **38**,908(1954)

**Beyling, Carl** (1871-1938). A Ger engineer specializing in mining expls. Author, in collaboration with K.Drekopf, of the book "Sprengstoffe und Zündmittel", Springer,Berlin(1936)

*Refs*: 1)H.Woltersdorf,SS **33**,333-4(1938) 2)H. Woltersdorf,Nobel Hefte,Feb 1939, enclosed in SS **34**(1939) betw pp 64 & 65(Carl Beyling, zum Gedächtnis)

**BF** (Poudre B de fusil). See under B(Poudre)

*Note*: Alvaro-Alberto,AnAcadBrasileiraCiencias **15**, No 1,pp 50-1(March 1943) gives compn of one of these older proplnts analyzed in Brazil: NC (12.7%N) 97.3,ether 0.8, ethanol 0.4 & moisture 1.5%

**BF•122 & BF•151** are composite polysulfide proplnts for rocket motors developed by the Thiokol Chem Corp. Their compn & props are given in conf Propellant Manual,SPIA/M2(1959),Unit Nos 570 & 571

**BFAM** (Poudre B, amyl alcool). See under B(Poudre )

*Note:* Alvaro-Alberto, AnAcadBrasileiraCiencias **15**, No 1,pp 50-1(March 1943) gives compn of one of these older proplnts analyzed in Brazil: NC(12.7%N) 95.1, amyl alc 2.0, ether 1.0, ethanol 0.5 & moisture 1.4%

**BFNL** (Poudre B à fusil,nitratée lavée). See under B(Poudre)

**BFP** (Poudre B en paillettes pour fusil de guerre). See under B(Poudre)

**$BFP_1$** (Poudre)(Série 389-SL-1931), described by

H.Muraour et al, in MP **35**,280(1953), consists of NC(13.2%N) 98.9, DPhA 0.9, & residual solvent (alcohol) 0.2%. It is in the form of square grains 1.54 x 1.54mm and 0.28mm thick

**BG** (Poudre B de guerre destinée à l'armée de terre). See under B(Poudre)

**BGC** (Poudre B de guerre pour gros calibre). See under B(Poudre)

**BGY.** A cast double-base proplnt for rocket motors developed at ABL. Its compn & props are given in conf Propellant Manual,SPIA/M2(1959),Unit No 575

**BHQ.** Ditto, Unit No 576

**Biacetylene.** Same as Butadiyne

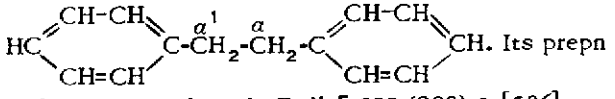
**Biazole.** Same as 1,3,4-Oxadiazole

**Biazzi, Mario**, of Vevey, Switzerland, is the inventor(1935) and producer of apparatus for continuous manuf of expls, such as NG, DEGDN, Nitrobenzene, Nitrotoluene, PETN, RDX, etc
*Refs*: 1)W.B.Littler & D.B.Clapp,BIOS Final Rept 1842k1946) 2)Stettbacher (1948), Advertisement at the back of the book 3)J.C.Smith, ChemInds **62**,929-31(1948) & CA **43**,1711(1949)(Biazzi process for continuous nitration) 4)H.J.Klassen & J.M.Humphreys, ChemEngProgr **49**,641-6(1953) & CA **48**,1683(1954)(Manuf of NG by the Biazzi continuous process) 5)Groggins(1958),747-9 6)A. Stettbacher, Explosivst **1959**,187

**Bibenzoyl.** Same as Benzil

### Bibenzyl and Derivatives

*Bibenzyl; sym-Diphenylethane or α, α'-Diphenylethane* (called α.β-Diphenyl-äthan or Dibenzyl in Ger),



. Its prepn and props are given in Beil **5**,598,(280) & [506]
*Note*: Y.Ch.Chatovedi,IndianP 44569(1952) & CA **47**,6443(1953) patented a method for the manuf of bibenzyl by bubbling HCl gas through a refluxing mixt consisting of dry benzene, dichloroethane and Al-Hg alloy turnings
*Mononitrobenzyl*, $C_6H_5.CH(NO_2).CH_2.C_6H_5$. One isomer is described in Beil **5**, 603
*Dinitrobibenzyl*, $C_{14}H_{12}N_2O_4$; mw 272.25, N 10.29%. Several isomers are described in Beil **5**, 603,604(283) & [508] of which the following is of importance because it can serve for prepn of expl higher nitro compds: *4,4'-Dinitrobibenzyl or p,p'-Dinitrobibenzyl*, $O_2N.C_6H_4.CH_2.CH_2.C_6H_4.NO_2$. Pale yel ndls, mp 179-182°. Was first obtained in 1866 by Stelling & Fittig on nitrating bibenzyl with concd nitric acid(Ref 1). Rinkenbach & Aaronson(Ref 3) improved the method by using a weaker acid(d 1.42). Green et al(Ref 2) prepd the dinitro-compd by air-alkali oxidation of p-MNT. Methods similar to Green's are described in detail in Refs 4 & 5. 4,4'-Dinitrobibenzyl can serve for the prepn of tetra-, penta- and hexanitrobibenzyls
*Refs*: 1)Beil **5**,604 & [508] 2)A.G.Green et al, JCS **91**,2079(1907) 3)W.H.Rinkenbach & H.A. Aaronson,JACS **52**,5040-1(1930) & CA **25**,508(1931) 4)R.C.Fuson & H.O.House,JACS **75**,1325-6(1953) & CA **48**,3316(1954) 5)OrgSynth **34**,35-6(1954) & CA **49**,5401(1955)
*Trinitrobibenzyl*, $C_{14}H_{11}N_3O_6$-not found in Beil or in CA thru 1956
**Tetranitrobibenzyl**, $C_{14}H_{10}N_4O_8$; mw 362.25, N 15.47%, OB to $CO_2$ -110.5%. The following isomer is known: *2,4,2',4'-Tetranitrobibenzyl*, $(O_2N)_2C_6H_3.CH_2.CH_2.C_6H_3.(NO_2)_2$; pale yel ndls, mp 168-172°; expl in 5secs at 380° but did not expl by impact of 2kg wt falling 34"; insol in w or ethanol; sl sol in eth or chlf; appreciably sol in ethyl acetate, hot benz, toluene, acetone, acetic acid or ethylene dichloride. Was prepd in 1916 by Braun & Rawicz(see in Ref 1) in 70% yield by nitration of bibenzyl with fuming nitric acid, with cooling. Rinkenbach & Aaronson(Ref 2) devised a method of nitration with nitric acid which permitted increasing the yield to 90% or even higher. Attempts to prep the tetra-compd by the use of nitric-sulfuric mixt gave negative results. Ogata & Oda(Ref 3) prepd the 2,4,2',4'-tetra-nitrobibenzyl by nitration of bibenzyl or of 2,2'-dinitrobibenzyl. Blatt & Rytina(Ref 4) prepd it by nitrating with 100% nitric acid either 4,4'-dinitrobibenzyl or bibenzyl. Rinkenbach & Aaronson(Ref 2) found that 2,4,2',4'-tetranitrobibenzyl could not be initiated by 0.4g MF or by the combination of 0.23g MF & 0.40g Tetryl when tested in a sand bomb. However, when 0.23g MF with 0.40g RDX was used for initiation complete deton took place. The sand test value of tetranitrobibenzyl was found to be 70% of that of TNT
*Refs*: 1)Beil **5**,(285) 2)W.H.Rinkenbach & H.A. Aaronson,JACS **52**,5041(1930) & CA **25**,508(1931) 3)Y.Ogata & R.Oda,BullInstPhysChemResearch (Tokyo) **21**,238(1942) & CA **43**,7918(1949) 4)A.H. Blatt & A.W.Rytina,JACS **72**,404(1950) & CA **45**,

1081(1951)

**2,4,6,2',4'-Pentanitrobibenzyl,** $C_{14}H_9N_5O_{10}$; mw 407.25, N 17.2%, OB to $CO_2$ -88.4%. Pale yel crysts, mp 187-8°. Was obtained together with hexanitrobibenzyl by Blatt & Rytina(Ref 2) on treating tetranitrobibenzyl with nitric-sulfuric acid and oleum. Its expl props were not detd

*Refs*: 1)Beil- not found 2)A.H.Blatt & A.W.Rytina,JACS **72**,404(1950) & CA **45**,1081(1951)

**2,4,6,2',4',6'-Hexanitrobibenzyl or 2,4,6,2',4',6'-Hexanitro-sym-diphenylethane,** $(O_2N)_3C_6H_2.CH_2.CH_2.C_6H_2(NO_2)_3$; mw 452.25, N 18.58%, OB to $CO_2$ -70.8%. Pale yel crysts, mp 213-218°. Will(Ref 2) claimed that he prepd the compd with mp 212° either by nitration of dinitrobibenzyl or by oxidation of α-TNT, but he gave no detailed procedures. Rinkenbach & Aaronson(Ref 3) obtained it in a very small quantity [together with a large amt of 2,4,2',4',6'-pentanitro-α-hydroxybibenzil, $(O_2N)_3C_6H_2.CH_2.CH(OH).C_6H_3(NO_2)_2$, also called α-2,4,6-trinitrophenyl-β-2,4-dinitrophenyl-hydroxyethane] when they nitrated the previously sulfonated tetranitrobibenzyl by a rather complicated procedure. Mecir(Ref 3a) claimed to have prepd the hexanitro-compd by treating α-TNT with an aq soln of Na sulfite

Parkes & Farthing(Ref 5) prepd the hexanitro compd by passing dry air for 5 hrs through a mixt of 5g TNT & 5g Na carbonate in 150ml water, heated on a water-bath. The mixt was then cooled, centrifuged and the solid(6g) was dried in a vacuum oven over concd sulfuric acid. Extraction with benzene in a Soxhlet left a residue(2.4g) of finely divided black solid which exploded on heating(its compn was not established). The benz extract was evaporated to ca 40ml and then left in a vacuum over concd sulfuric acid. White ndls formed at the bottom of the soln and then TNT on the walls of the dish. The white ndls were separated(0.2g) and recrystallized from toluene. The purified material had mp 216-17°. Blatt & Rytina(Ref 6) prepd a small quantity of the hexanitro-compd with mp 213-15° by prolonged nitration of pentanitrobibenzyl (previously obtained by nitration of the tetranitro-compd) with nitric-sulfuric acid mixed with oleum

Blatt(Ref 4) stated that hexanitrobibenzyl is less powerful and less brisant expl than PA

*Refs*: 1)Beil **5**,(285) 2)W.Will,Ber **47**,704(1914) 3)W.H.Rinkenbach & H.A.Aaronson,JACS **52**,5044-5(1930) & CA **25**,508(1931) 3a)J.Mecir,Chim & Ind(Paris) **1933**,Special No,pp 952-9 & CA **28**,645(1934) 4)Blatt,OSRD **2014**(1944) 5)G.D.Parkes & A.C.Farthing,JCS **1948**,1277 & CA **43**,592(1949) 6)A.H.Blatt & A.W.Rytina,JACS **72**,404(1950) & CA **45**,1081(1951)

**BIC.** A cast double-base proplnt, developed at ABL. Its compn & props are given in conf Propellant Manual,SPIA/M2(1959),Unit No 577

**Bicarbamyl Azide**(called Hydrazodicarbonazid or Hydrazin-N,N'-dicarbonsäure, in Ger), $N_3.CO.NH.NH.CO.N_3$; mw 170.10, N 65.88%, OB to $CO_2$ -28.2%. Crysts, mp 150-2° (with vigorous evoln of gas); expl violently on rapid heating above the mp. Very sol in eth; easily sol in alc, acet or hot ethylene bromide; sl sol in w; insol in chlf or benz. Can be prepd in small yield by diazotizing bi(carbamyl) hydrazide. It is a primary type expl similar to LA and AgA; impact sensitivity 70cm using 100g wt, vs 80-85cm for LA and initiating ability is approx the same as that of LA (0.25g required to deton lg of molten TNT)

*Refs*: 1)Beil **3**,(60) & [102] 2)W.Kesting,Ber **57B**,1321-3(1924) & CA **19**,245(1925)

**Bicarbite or Bikarbit.** A dynamite consisting of NG 15, bicarbonate 50 & NaCl 35%(Ref 1). Its props are described in Ref 2

*Refs*: 1)Beyling & Drekopf(1936),145 2)PATR **2510**(PB No **161270**)(1958),p Ger 11

**Bicarbonates.** See under Carbonates

**Bichel,Christian E.** (1857-1914). A Ger scientist and artillery officer who specialized in industrial expls. Inventor of the Bichel Bomb, several expl compns and author of several papers on physical testing of expls and of the book:"Untersuchungsmethoden für Sprengstoffe", W.Ernst,Berlin(1905)

*Ref*: W.König,SS **10**,73-4(1915)(An obituary)

**Bichel Bomb or Bichel Pressure Gage.** See p VIII, under Physical Tests in Vol 1 of this encyclopedia

**Bichel Calorimetric Bomb** is a heavy-walled cylindrical steel bomb with a removable cover used for detn of the amt of heat liberated during an expln (heat of expln). The original bomb had a 30-liter capacity and was intended for use with a 100g sample. Later models of the bomb were smaller and 10g samples were used

A different kind of Bichel Bomb, known also as Bichel Pressure Gage has been used for detn of pressure of expln and for collecting and examining products of expln

*Refs*: 1)Stettbacher(1933),84 2)PATR **2700**(1960), Vol 1,p VIII

**Bichel Explosives.** The following expl mixts were patented by Bichel: a)Mixts of nitric acid and kieselguhr packed in plastic cartridges(Ref 1,p 67) b)Mixts of hydrocarbons(preferably oils) satd with 28-30% of pulverized sulfur, with nitrates, chlorates, NG, nitromannite, etc; such as:sulfurated turpentine 3 parts and NG 10ps or sulfurated tar oil 10ps, nitrocumol 5ps and Na nitrate 90-100ps (Ref 1,p 68) c)Blasting expl: AN 86, TNT 8 & flour(or starch) 6%(Ref 1,p 68) d)Blasting expl: TNT 85, liq oleoresin(such as storax) 4.5, DNT 10 & collodion cotton 0.5%(Ref 2)
*Refs* 1)Daniel(1902),67-8 2)C.E.Bichel, USP 896887(1908) & CA **2**,3283(1908)

**Bichel Pressure Gage.** See Bichel Bomb,p VIII, vol 1 of this Encyclopedia

**Bichel Recording Pressure Gage.** Same as above. See also Marshall **2**(1917),445-7

**Bichromates.** See Dichromates under Chromates and Dichromates

**Bickford Fuse or Miner's Safety Fuse** is a device patented in 1831 by William Bickford of Cornwall, England, for firing blasting charges safely. It replaced older methods of firing, which consisted either of igniting a train of black powder laid up to the blasting charge or of using a quill(or rush) filled with black powder as an igniter. As the time taken by these older devices to burn was very uncertain many accidents took place during firings because the personnel did not withdraw from the danger zone in time. The Bickford fuse did away with this uncertainty because the rate of burning is definite

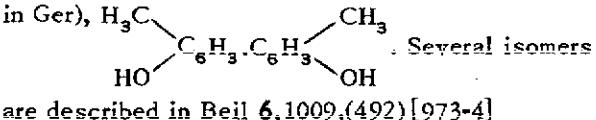
The original Bickford fuse consisted of a central thread surrounded by a core of black powder enclosed within a tube of woven threads, such as jute. This could be surrounded by various layers of textile and, in order to make the fuse waterproof, it could be varnished on the outside. Sometime before 1840 a guttapercha-covered fuse, designed for underwater work was adopted. Since then, many other modifications have appeared including a fuse cased in metal, the so-called *Colliery Fuse*, which emits no sparks(1886), and the *Instant Fuse*, which burns very rapidly and enables many shots to be fired simultaneously

The manuf of Bickford fuses began in the US in 1836, in France 1839 and in Germany 1844. The name of the current US firm is "The Ensign-Bickford Co" which is located at Simsbury, Conn. This company manufactures many varieties of fuses, among them the detonating fuses, such as *Cordeau Bickford*, a lead tube filled with TNT, and *Primacord Bickford*, a tube of waterproof textile filled with desensitized PETN(see also Fuses)
*Refs*: 1)Daniel(1902),428-33(Mèches de sûreté) 2)Marshall **1**(1917),38; **2**(1917) & **3**(1932),165-8 3)Davis(1943),11-14 4)Blasters'Hdbk(1952),87-90

**Bickford Igniter or Igniter Fuse.** When working in gaseous mines, it is important not to use an open flame for igniting the safety fuse, but to use some flameless device. One of the older devices was the *Bickford Igniter*, which consisted of a metallic tube of tinned iron or steel to be fitted to the free end of the fuse(the end to be ignited). This tube, closed at one end, contained a small glass capsule with concd sulfuric acid and a pellet of K chlorate-sugar mixt. By pinching the metal tube, the capsule was broken and the liberated acid ignited the chlorate-sugar which in turn ignited the black powder in the core of the fuse. When the fire reached the other end of the fuse, a spit of flame shot into the blasting cap and this detonated the explosive(see also Fuse Lighters)
*Ref:* Marshall **2**(1917),538

**Bickford & Smith's Primary Mixture**, patented in 1898 consisted of Na tungstate, Sr nitrate, Sb sulfide, K chlorate, graphite and ppted Cu of Ag
*Ref*: Daniel(1902),70

## Bicresol and Derivatives

*Bicresol; Dihydroxydimethylbiphenyl or Dihydroxybitolyl*(Dicresol)(called Dioxy-dimethyl-diphenyl in Ger),  . Several isomers are described in Beil **6**,1009,(492)[973-4]
*Mononitrobicresol*, $C_{14}H_{13}NO_4$. One isomer is described in Beil **6**,1010
*Dinitrobicresol*, $C_{14}H_{12}N_2O_6$. One isomer is described in Beil **6**,1010 & [974]
*Trinitrobicresol*, $C_{14}H_{11}N_3O_8$ - not found in Beil or in CA thru 1956
**Tetranitrobicresol**, $C_{14}H_{10}N_4O_{10}$; mw 394.25, N 14.28%. One isomer: *2,6,2',6'-Tetranitro-4,4'-bi-m-cresol* is described in the literature. Yel crysts (from et acet), mp 299°; insol in ether & petr eth; sl sol in hot alc, w & ethyl acet; easily sol in hot benz. Was prepd by Steinkopf et al by heating with weak nitric acid the product obtained on diazotization of m-toluidine hydrochloride. Its expl props were not investigated. Forms salts, such as those

of Amm and of Na
*Refs*: 1)Beil **6**,[973] 2)W.Steinkopf et al,JPrakt-Chem **110**,355(1925) & CA **20**,187(1926)
*Note*: No higher nitro compds and no later info on the above compds were found in CA through 1956

**"Bicycle Pistol"** (Radfahrer-Pistol, in Ger). This name is mentioned in SS **6**,398(1911) & CA **6**,547 (1912) in connection with an expln in the Berlin post office, but no description of pistol is given

**Bicyclopentamethylene-2,4,6,8-tetramine;2,6-Dinitro(DPT).** See 3,7-Dinitro-1,5-endomethylene-1, 3,5,7-tetraza-2,4,6,8-cyclooctane under 1,5-Endomethylene-1,3,5,7-tetraza-2,4,6,8-cyclooctane

**BID.** A cast double-base proplnt developed at ABL. Its compn & props are given in conf Propellant Manual SPIA/M2(1959),Unit No 498

**BIE.** Ditto, Unit No 499

**Bielefeld Explosive**, patented in 1896 for use in coal mining, consisted of Na nitrate 69, K nitrate 5, sulfur 10, coal tar 12 & K dichromate 4%
*Ref*: Daniel(1902),70

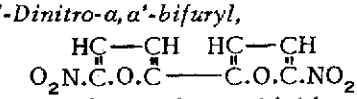
**Bielefeld's Gelatinization Method**, patented in Germany in 1896-7, consisted of treating expls, such as NG, nitrobenzene, nitromolasses, aromatic nitrocompds, etc per se or in the presence of drying oils, resins, alcohol, etc with sulfur monochloride($S_2Cl_2$) at very low temps. The resulting jelly was mixed with oxidizers, such as nitrates, and with fuels, such as sawdust, flour, etc and then cartridged(compare with Parke's Absorbents)

**Bifuel Rocket Engine.** Same as Bipropellant Rocket Engine

### Bifuryl and Derivatives

*α,α'-Bifuryl*(2,2'-Difuryl or-α,α'-Difuryl),$C_8H_6O_2$; is described in Beil **19**,[26]

*5,5'-Dinitro-α,α'-bifuryl*,



, mw 224.13, N 12.50%. Yel-brn prisms with blue reflection(from benz), mp 213-4°; insol in alkalies & dil acids. Was first prepd by Marquis in 1905(Ref 2)by treating furan with fuming nitric acid(d 1.51) in presence of acetic anhydride. The yield was poor. Rinkes (Ref 3) prepd it on heating 2-bromo-5-nitrofuran with the activated Cu powder of J.Piccard. The yield was poor but better than that of Marquis. Rinkes also proved the structure of the dinitro -compd
*Refs*: 1)Beil **19**,32 2)R.Marquis,AnnChimPhys[3] **4**,223 & 225(1905) 3)I.J.Rinkes,Rec **50**,981-5 (1931)& CA **26**,982(1932)
*Trinitro-*,$C_8H_3N_3O_8$ and *Tetranitro-*,$C_8H_2N_4O_{10}$ *Derivatives* were not found in Beil or in CA thru 1956

**Big Bertha; Paris Gun and Other German Big Guns of WWI and WWII.** Many big guns were developed in Germany some of them with a max range of ca 120km. Following is an incomplete list of such guns:
a) *Paris Gun(Parisgeschütz) or Long Range Gun (Ferngeschütz)* was a 21cm(ca 8") weapon with the length of the tube 34m. Its max range was 120km. As the life of these guns was only 50-60 rounds, they were rebored to 240mm and later to 260mm (Ref 1). According to Ley(Ref 3), the guns 21cm L/150 and 23.5cm L/132 were known as Paris Guns. The official Ger name for both of these guns was *Kaiser Wilhelm Geschütz*. The gun crews made no distinction between the two types and used the nickname *Die Pariserin*(La parisienne, in Fr). These guns were sometimes eroneously called Big Berthas b)24cm L/30 to L/40 Guns, such as *Theodor, Theodor Bruno, Naval, Seacoast* and *Krupp*(Refs 3 & 6) c)24.4cm Howitzer, presumably called *Alpha*(Ref 3) d)28cm L/40 to L/50 Guns, such as *Bruno, Theodor Bruno, Leopold(Anzio Annie)*, Railway and Naval(Refs 5 & 6) e)28cm L/12 & L/14 Coast Howitzers*(Schwere Küstenhaubitze)*(Refs 3 & 6) f)30.5cm L/50 Naval and Seacoast Guns(Ref 6) g)30.5cm L/17 Howitzer, nicknamed *Kartaune* in honor of the Ger 15th century gun(Ref 3) h)30.5cm L/12 Howitzer(Mortar) *(Schwere Küstenmörser)* and 30.5cm L/16 Howitzer, called *Beta 09 L/16*(Ref 3) i)31.0cm *Glött* Gun on Railway Mount(Ref 6) j)35 or 35.5cm Howitzer M-1(Ref 6) k)35.6cm L/52.5 Gun, built by the Krupp Co for the Greek battleship *Basileos Gheorgios* but requisitioned by the Germans before it was delivered(Ref 3) l)38.0cm *Siegfried* Railroad Gun, and 38cm Naval Gun c/34(Ref 6); m) 38.1cm L/45 Coast Defense Gun, nicknamed *Lange Emil*(Ref 3) n)40.6cm *Adolf* Gun(Ref 6) o)42.0cm Howitzer, called *Gamma Mörser*(Ref 6) p)42.0cm L/14 Howitzer(Mortar), designated as *KMK L/14(Kurze Marine Kanone, Länge 14)* and nicknamed *Dicke Bertha*(Fat Bertha, not referring to Frau Bertha von Krupp), *Dickes Luder*(Fat Wench) or *Tante aus Essen*(Aunt from Essen), cal-

led in English *Big Bertha*(Refs 3 & 6). This weapon fired a projectile weighing ca 1 ton to a distance of ca 11 miles(Ref 5). These guns were constructed during WWI q)42.0cm L/16 Howitzer, called *KMK Gamma or Eisenbahn 42*(Railroad, model 1942) (Ref 3) r)53.34cm Gun, designated as *Gerät 36* (Ref 6) s)54.0cm Heavy Howitzer, called *Karl Mörser or Karl Gerät*(Ref 6). According to Jarrett, "Achtung Panzer",Great Oaks,RD 1,Aberdeen,Md (1948),p 98, there were 54.0cm and 61.0cm weapons called *Thor* and*Karl* Mortars, but, according to Ley(Ref 3), the *Thor* was likely to be a 61.0cm weapon t)61.0cm *Thor Mörser* It was used during WWII at the siege of Sevastopol(Ref 6,p Ger 263) u)61.5cm *Karl Mörser*(Ref 6). According to Ley(Ref 3), the Germans used at the siege of Sevastopol the following super-heavy weapons: 61.0cm rifled mortar(short howitzer); 69.0cm short, rifled Naval gun, railroad mounted;and 71.5cm rifled mortar(short howitzer) v)80.0cm Gun, nicknamed *Dora* or *Gustav Geschütz,* was used during WWII at the siege of Sevastopol and for this reason was known as *Sevastopol Gun.* Porter(Ref 4) calls it *Big Bertha of WWII.* A brief description of the Sevastopol Gun is given in Ref 4 and in Ref 6,pp Ger 176 & 259. The above gun was sometimes referred to as the 82.0cm gun

*Refs*: 1)H.W.Miller,ArmyOrdn **4**,98-100,122 & 167 -176(1923)(The German Long-Range Gun) 2)H.W. Miller,ArmyOrdn **16**,10-17(1935)(Behind the Paris Gun) 3)W.Ley, Coast Artillery Journal,Jan-Feb **1943**,pp 14-15 4)F.B.Porter,ArmyOrdn **31**,254-6 (1946)(Big Bertha of WWII) 5)G.B.Jarrett,Ordn **35**, 397-8(1951)(That Fabulous 1918 Paris Gun Again) 6)PATR **2510**(PB No 161,270)(1958),pp Ger 257-9

*Note*: According to Ref 5,p 398, there was a book by H.W.Miller, "The Paris Gun", published in 1930

**Big Inch Blasting Cap, Western.** See under Blasting Caps

### Biguanide and Derivatives

*Biguanide or Guanylguanidine*(called Guanidincarbonsäureamidin in Ger),$H_2N.C(:NH).NH.C(:NH).NH_2$, mw 101.12, N 69.27, OB to $CO_2$ -118.7%. Prisms (from abs alc in $CO_2$atm), mp 130°; very sol in w and in alc; insol in eth, benz or chlf. Can be prepd from cyanoguanidine(dicyandiamide), $H_2N.C(:NH).NH.CN$, by one of the methods described in the literature(Refs 1 & 2)

Many of its salts(some of them explosive) can easily be prepd by heating(or fusing) cyanoguanidine(dicyandiamide) with the corresponding Amm salt in the propn of 2 to 1 resp

*Refs*: 1)Beil **3**,93,(44) & [76] 2)E.C.Franklin, "The Nitrogen System of Compounds", Reinhold,NY (1935),97-98 3)R.L.Sperry & E.O.Hook,USP2371111 (1945) & CA **39**,3545(1945), BritP 579867(1946) & CA **41**,1700(1947)(Prepn of biguanide and alkyl biguanides from the corresponding Cu biguanide sulfates) 4)P.Oxley & W.F.Short,JCS **1951**,1253 & 1255(Prepn of biguanide by heating an equimol mixt of cyanoguanidine & ammonium sulfonate) P. Rochlin,D.B.Murphy & S.Helf,JACS **76**,1453(1954) & CA **49**,3951(1955)(Relative basicity of biguanide)

**Biguanide Complex Compounds With Bivalent Metals** were studied by P.Rây et al, JIndianChemSoc **16**, 617-20(1939); **18**,217-24(1941); **18**,609-22(1941); **18**, 289-306(1941); **18**,609-22(1941); **20**,19-21(1943) **20**, 291-7(1943); **21**,163-6(1944); **25**,563-70(1948); **26**, 144-8(1949); **27**,411-15(1950);**27**,651-4(1950); [see also CA's: **34**,4683(1940); **36**,718(1942); **36**, 2804-5(1942); **36**,5440(1942); **37**,6578(1943); **39**, 4559-60(1945); **43**,7365(1949); **43**,8941(1949); **45**, 6594(1951); **45**,8390(1951)]

**Biguanide Complex Compounds With Trivalent Metals** were studied by P.Rây et al, JIndianChem Soc **14**,670-84(1937); **15**,347-58(1938); **15**,633-8 (1938); **16**,621-33(1939); **23**,73-84(1946);**25**,589-90 (1948); **26**,137-43(1949)

[see also CA's: **32**,3721(1938); **33**,493-4(1939); **33**, 5314(1939); **34**,4683-4(1940); **41**,44-6(1947); **43**, 7365(1949); **43**,8941(1949)]

**Biguanide Complex Compounds With Tervalent Metals** were studied by P.Rây et al, JIndianChem Soc **19**,1-8(1942) & CA **36**,5721-2(1942)

**Biguanide Explosive Salts** include **Biguanide Chlorate.** See under Biguanide Perchlorate and Chlorate

**Biguanide Nitrate,** $C_2H_7N_5.HNO_3$; prisms(from w), mp 192°. Can be prepd by fusing cyanoguanidine with Amm nitrate. Manuelli & Bernardini(Ref 2) proposed using biguanide nitrate as an ingredient of expl compns

*Refs*: 1)Beil **3**,(44) & [76] 2)C.Manuelli & L. Bernardini,BritP 138371(1917) & CA **14**,2086(1920) 3)T.L.Davis,JACS **43**,2235(1921) 4)J.S.Blair & J.M.Braham,JACS **44**,2349-50(1922)

**Biguanide Perchlorate and Chlorate** can be prepd by heating cyanoguanidine with Amm perchlorate or chlorate resp. They were proposed by Manuelli & Bernardini(Ref 2) for use in expls

*Refs*: 1)Beil- not found 2)C.Manuelli & L.Bernardini,BritP 138371(1917) & CA **14**,2086(1920)

**Biguanide Picrate,** $C_2H_7N_5.C_6H_3N_3O_6$; yel ndls (from w), mp 232°; sl sol in w and in alc. Can be prepd either by the action of an aq soln of PA on biguanide(Ref 1) or from biguanide sulfonate and

Amm or Li picrate solns(Ref 2). Its expl props were not investigated

*Refs*: 1)Beil **6**,279 2)P.Oxley & W.F.Short,JCS **1951**,1255

**Biguanide, Analytical Procedures** are described in the following Refs:

1)J.S.Blair & J.M.Braham,JACS **44**,2347(1922) (Method of detn of biguanide based on the insoly of *Ni* biguanide in alkaline soln) 2)C.D.Garby, IEC **18**,819(1926) Detn of biguanide as its Ni salt, $Ni(C_2H_6N_5)_2$

### Biguanidine and Derivatives

*Biguanidine(Hydrazobisformamidine or Hydrazodicarbonamidine)*, $H_2N.C(:NH).NH.NH.C(:NH).NH_2$, mw 116.13, N 72.36%. Its dinitrate, $C_2H_8N_6.2HNO_3.H_2O$, crysts, mp 132°(with evoln of gas); defl at 181°; was prepd by Thiele, Many derivs of biguanidine, including the dinitro comp, are known but no description of biguanidine itself could be found

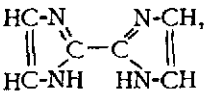
*Refs*: 1)Beil**3**,120 2)J.Thiele,Ann **270**,42(1892) & **273**,140(1893)

**1,6-Dinitrobiguanidine**, $O_2N.HN.C(:NH).NH.NH.C(:NH).NH.NO_2$, mw 206.14, N 54.36%. Col crysts, mp 193-5° with vigorous decompn. Henry et al(Ref 2) prepd it in 20-25% yield by the reaction of nitroaminoguanidine and 1-methyl-1-nitroso-3-nitroguanidine or in 55% yield by the hydrogen sulfide reduction of azobisnitroformamidine

*Refs*: 1)Beil- not found 2)R.A.Henry,S.Skolnik & G.B.L.Smith,JACS **75**,955 & 958(1953); CA **48**, 2050(1954)

### Biimidazole and Derivatives

*Biimidazole,[called Diimidazyl-(2.2') in Ger]*,



mw 134.14, N 41.77%. Ndls which sublime without melting. Was prepd in 1859 by H. Debys under the name of *Glycosin*(Ref 1). Several metallic and org salts are known(Refs 1,2 & 3)

*Refs*: 1)Beil **26**,358,(111) & [214] 3)K.Lehmstedt, Ann **456**,253(1927) & CA **21**,3364(1927) 3)K. Lehmstedt,Ann **507**,213-25(1933) & CA **28**,767(1934)

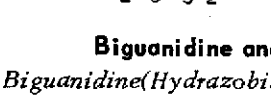
**1,4'(or 1,5')-Dinitrobiimidazole**[called *1.4'(bzw 1.5')-Dinitro-diimidazolyl-(2.2')* in Ger], $C_6H_4N_6O_4$, mw 224.14, N 37.50%. Yel lflts with $1H_2O$, mp 283° (dec); weak expl. Was obtained by Lehmstedt as a by-product during prepn of tetranitrobiimidazole (qv). Its salts are reddish in color

*Refs*: 1)Beil **26**,[215] 2)K.Lehmstedt,Ann **456**, 271(1927) & CA **21**,3364(1927)

**1,5,4'(or 1,5,5')-Trinitrobiimidazole**[called *1.5.4'-(bzw 1.5.5')-Trinitro-diimidazolyl-(2.2')* in Ger], $C_6H_3N_7O_6$, mw 269.14, N 36.43%. Lt brn lflts with $1.5H_2O$; expl on rapid heating; very diff sol in w, alc or eth. Was obtained by Lehmstedt as one of the products of nitration of biimidazole. Its salts are dark red in color

*Refs*: 1)Beil **26**,[215] 2)K.Lehmstedt,Ann **456**, 270(1927) & CA **21**,3364(1927)

**1,5,1',5'-Tetranitro-2,2'-biimidazole** [called *1.5.1',5'-Tetranitro-diimidazolyl-(2.2')* in Ger],



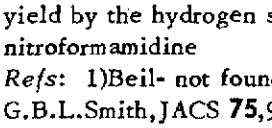
, mw 314.14, N 35.67%. Yel prisms with $2H_2O$, mp- dec ca 276° and is very explosive. Sol in w, alc, ether or ethyl acetate. Can be prepd by nitration of biimidazole with concd nitric and sulfuric acid as described in Refs 1 & 2

*It forms salts, most of which are explosive.* Eg: *Disodium salt*, $Na_2C_6N_8O_8.2H_2O$, orange-red crysts, expl on heating; *Dipotassium salt*, $K_2C_6N_8O_8.2H_2O$, red-brn ndls, expl on heating; *Disilver salt*, $Ag_2C_6N_8O_8.2H_2O$, gelatinous brn ppt, expl on heating

*Refs*: 1)Beil **26**,[215] 2)K.Lehmstedt,Ann **456**, 272-3(1927) & CA **21**,3364(1927)

### Biimidazoline and Derivatives

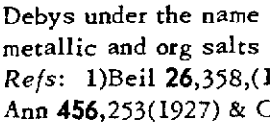
*2,2'-Bi-(2-imidazoline) or Bis-($\Delta^2$-2-imidazolinyl)* [called *Di-[$\Delta^2$-imidazolinyl-(2)]* in Ger],



, mw 138.17, N 40.55%. Prepn and props are described in Refs. Forms salts, such as *picrate*, yel powder melting with decompn at 272-3°

*Refs*: 1)Beil **26**,353 2)G.Forssel,Ber **24**,1846 (1891) & **25**,2132(1892) 3)H.M.Woodburn & R.C. O'Gee,*JOC* **17**,1236 & 1241-2(1952) & CA **47**, 8066(1953)

*2,2'-Bi-(1-nitroso-2-imidazoline)*[called *Bis-[1-nitroso-$\Delta^2$-imidazolinyl-(2)] in Ger*],



, mw 196.17, N 42.84%; greenish ndls(from alc), mp 173° (dec). Was prepd by Forssel by treating 2,2'-bi-(2-imidoline) with K nitrite and concd AcOH

*Refs*: 1)Beil **26**,363 2)G.Forssel,Ber **25**,2133 (1892)

*Note:* No mono- or di-nitro compds were found in Beil or in CA through 1956

**Bikarbit.** Same as Bicarbite

**BIL** and **BIM** are cast double-base proplnts developed at ABL. Their compn and props are given in conf Propellant Manual SPIA/M2(1959), Unit Nos 500 & 501

**BINARY, TERNARY AND QUATERNARY MIXTURES.** These mixts may consist of two, three or four components being either exclusively expls or one or more expls with non-expls, such as oxidizers(AN, K chlorate, K perchlorate, Ba nitrate, peroxides, etc), pulverized fuels(such as C, Al, Mg, Zr, etc) or fuels which may act as binders, desensitizers or waterproofing agents(such as wax, paraffin, shellac, resins, plastics, etc)

These mixts can be either eutectics(partly or completely) or non-eutectics and the purposes of the mixts can be as follows:

a) To facilitate cast-loading into shells, bombs, warheads of rockets, etc, of high mp expls, such as PA, PETN or RDX

b) To improve the expl characteristics of some HE's, such as mixing them with oxidizers or pulverized metals

c) To stretch an insufficient supply of some expls (such as TNT), which might accur during a war

d) To render some expls(such as PETN, RDX or Tetryl) less sensitive to mech action, which can be accomplished by mixing them with wax, paraffin, etc

*Historical.* If one does not take into consideration BkPdr, which is a ternary mixt of an oxidizer(K nitrate) and fuels(C & S), and the unsuccessful attempts of Berthollet, Augendre and Blake(see Ref 4b,p 309) to improve BkPdr by replacing K nitrate with K chlorate, the first successful mixts suitable for blasting and for some military purposes were expls proposed beginning in 1871 by H. Sprengel. These expls were liquid and solid. The liq expls consisted of a liq oxidizer(such as strong nitric acid or nitrogen peroxide) and a liq or solid fuel (such as MNB, MNN, PA, petroleum, etc). The solid Sprengel expls, now known as *Cheddites*, consisted of an oxidizer(chlorate or perchlorate) and a fuel(PA, MNB, MNN, etc) (Ref 5a,p 354). E.Street rendered Cheddites less sensitive to mech action by incorporating some castor oil(or other desensitizer). These mixts were sometimes called *Street Explosives or Streetites*(Ref 4a,p 310). Later composite expls, *Anilithe, Hellhofite, Oxonite, Oxyliquite, Panclastite, Promethée, Rack-a-Rock*, etc, were only modifications of Street expls. However, none of these expls was suitable for loading shells. The same may be said about *Dynamites*, invented by A.Nobel, although some attempts were made to use them for shell loading. Many Dynamites are, however, suitable as military demolition expls. Dynamites contg collodion cotton are called *Gelatin Dynamites* and the strongest of such mixts is *Blasting Gelatin.* Stettbacher(Ref 12b) proposed in 1929 an expl mixt known as *Pentrinit* which may be considered as a non-freezing, very powerful dynamite and which is suitable for military purposes. It consisted of NG and at least 20% of PETN. By incorporating 4 to 6% of collodion cotton in such mixts, the so-called *Gelatinpentrinits* were obtained

One of the first known castable military expl mixt is probably the French *Mélange DN 60/40*, also called *DD 60/40*, developed with the intention of overcoming the difficulty of cast-loading straight *Mélinite* (PA). In the DD 60/40 expl: PA60 & DNPhenol 40%, the 2nd component lowers the mp of PA from ca 122° to ca 85°, while at the same time it reduces the expl characteristics of PA(Ref 15). Many other binary, ternary, etc mixts were developed in France in addn to DD 60/40 and most of them are listed in this section

Many of the mixts developed during WWI in Germany, GtBritain, Russia and the US were intended to stretch the available supply of TNT and of other HE's. The most important of such compositions were mixts of AN and TNT, called *Amatols.* As the shortage of TNT and of other HE's was even more acute in Germany during WWII than during WWI, many substitute expls(called *Ersatzsprengstoffe)* were developed. Some of these expls consisted of NaCl and TNT. To a lesser extent this shortage of TNT was felt in Russia(Ref 9a & 12c). The US and GtBritain were, however, fortunate to obtain during WWII an abundant supply of TNT due to the Amer development of synthetic toluene from petroleum. This abundance of TNT rendered practical the development of new binary, ternary, etc mixts in which TNT was utilized as a carrier for more powerful expls(such as PA, Tetryl, PETN, RDX, EDNA, etc), which alone were not suitable for cast-loading because of high mp's. The resulting mixts are known as *Picratols, Tetratols, Pentolites, Cyclotols, Ednatols*, etc. Another development in the direction of binary and ternary expl mixts was the incorporation of Al powder. These mixts, known as *Aluminized Explosives*, are described in Vol 1,p A146-L and have pronounced increased blast effects(Ref 15)

Binary mixts and their eutectics were examined by many investigators, such as Giua(Ref 1), Wogrinz & Vári(Ref 1c), Taylor & Rinkenbach(Refs 2,3 & 3a), Urbański(Ref 4a), Campbell et al(Refs

10,11 & 12), Ficheroulle(Ref 12a), Desseigne(Ref 13) & Yamasue et al(Ref 17)

Ternary mixts were investigated by Tomlinson (Ref 6), Phillips(Ref 7), Aaronson(Ref 8), Eriksen (Ref 9), Campbell et al(Refs 10 & 11) and Médard (Ref 13c)

Some quatenary mixts were used in Germany during WWII, eg: *Ammonit S-6* which consisted of TNT 40, HNDPhA 30, GuN 20 & Al Powder 10%; and *KMA Block* which contained TNT 40, HNDPhA 30, DNN 20 & Al powder 10%(Ref 17, p Ger 44)

Thomas(Ref 16) described a method of analysis of some binary expls using a solvent for separating the components

The following is a selected list of binary, ternary, and quaternary expls, foreign and US:

**Belgium** *Alsilite*(see Vol 1,p A141-R); *Baelenites* (see Vol 2); *Casteau*(AN 90 & nitrodextrin 10% with or w/o 5% resin added); *Centralite TA*(AN 79.5, TNT 14.5, RDX 2.0, DNT 1.0 & Al powder 3.0%); *Coopalite*(AN 79, TNT 13, NG 4 & woodflour 4%); *Dynamite III*(AN 62.0, NG 26.0, DNT 9.5, cellulose 1.3 & NC 1.2%); *Favier Explosives*(mixts of AN with DNN, TNT & other ingredients); *Macarite*(Pb nitrate 71.9 & TNT 28.1%); *Mégadyne*(mixt of Amm perchlorate, Al powder & paraffin wax); *Permite*(AN 78, TNT 8 & Ca silicide 14%); *Vélterine*(AN 93 & Amm trinitrocresylate 7%); *Wallonite*(AN 90 & Nitrotar 10%); *Yonckites*(mixt of Amm perchlorate with MNN, TNN, TNT and other ingrediants) [Dr L.Deffet,Bruxelles, private communication(1954) and other sources]

**France**: *Ammonal(AN 82, TNT 6, DNT 5, Al 5 & woodmeal 2%)*(See also Vol 1,p A290 Table); *Crésylite 60/40*(Trinitro-m-cresol 60 & PA 40%); *Explosifs nitratés & Explosifs nitratés à l'aluminium* (See N2TN, NDNT, NT, NTN, NX and Refs 5a & 13a); *Explosif S(or Sc)*- same as Schneiderite; *MDN or MFDN*(PA 80 & DNN 20%); *MDPC*(PA 55, DNPh 35 & TNCrs 10%); *Mélinite O*- see MO; *Mélinite P*- see MP; *MMn*(PA 70 & MMN 30%); *MO* (Mélinite O)(PA with some TNCr); *MP*(Mélinite P) (PA 88 & paraffin 12%); *MTTC*(PA 55, TNT 35 & TNCrs 10); *MTX*(PA 55, TNT 35 & TNX 10% or PA 30, TNT 25 & TNX 45%); *N2TN*(AN 50, Na nitrate 30 & TNN 20%); *NDNT*(AN 85, DNN 10 & TNT 5%); *NT*(AN 70 & TNT 30%); *NTN*(AN 80 & TNN 20%);*NX*(AN 77 & TN-m-xylene 23%); *Panclastites* of Turpin(mixts of liq fuels such as MNB gasoline, $CS_2$ with liq nitrogen peroxide)(Compare with Anilithe, described in Vol 1,p A443-R); *Schneiderite or Explosif Sc(or S)*(AN 87-8 & DNN 13-12%), *Xylite P*(PA 50, TNT 40 & TN-m-xylene 10%) [Refs 4b, 5a and the books of Pascal(1930), Venin,Burlot & Lécorché(1932) and Pepin-Lehalleur (1935)]

**Germany**: *Amatol 39*(DNB 50, AN 35 & RDX 15%); *Amatol 40*(DNAns 50, AN 35 & RDX 15%); *Amatol 41*(AN 52, tech Ca nitrate 6, EDADN 30, RDX 10 & montan wax 2%); *Ammonal I*(AN 54, TNT 30 & Al 16%); *Ammonal II*(AN 72, TNT 12 & Al 16%) (Ref 18,p Ger 4); *Ammonit 43C*(AN 45, tech Ca nitrate 10, GuN 15 & TNT 30%; emulsifier, "Vultamol", added 0.5%); *Ammonit H1*(AN 50, tech Ca nitrate 15, PETN 10 & RDX 25%) (Ref 18,p Ger 6); *Ammonit H8*(AN 50, K nitrate 25, RDX 15 & PETN 10%); *NaCl Explosive*(TNT 40-50 & NaCl 40-50%) (Ref 18, p 44); *Fillers 32 to 38*(PETN-Wax in various propns); *Filler 45*(PETN 50 & TNT 50% with 30% wax added); *Filler 52*(DNB 50, AN 35 & RDX 15%); *Filler 86*(EDADN 46, RDX 18 & wax 36%); *Filler 92-H10*(RDX 90 & wax 10%); *Filler 105 or Trialen 105*(RDX 15, TNT 70 & Al powder 15%); *Filler 106 or Trialen 106*(RDX 25, TNT 50 & Al 25%); *Filler 107 or Trialen 107*(RDX 20, TNT 50 & Al powder 30%); *Filler 108 or Tritolital*(RDX 20, TNT 60 & Al 20%); *Filler 109 or Trialen 109* (RDX 70, Al 25 & wax 5%)(Ref 18,pp Ger 46-8); *Hexamin Explosives*(such as HNDPhA 27.9, TNT 55.7 & Al 16.4%)(Ref 18,p Ger 88); *Monakit I*(An 81, K or Na nitrate 5, TNX 13 & flour 1%)(Ref 18, p Ger 114); *Nitrolit*(TNAns 60 & AN 40%)(Ref 18, p Ger 122); *Pentritols*(PETN/TNT in various propns)(Ref 18,p Ger 128); *PH-Salt Explosives* (see Ref 18,p Ger 132), *R-Salt Explosives*(see Ref 18,p Ger 70); *Trialen*(see Fillers 105, 106, 107 & 109); *Tritolital*(see Filler 108); *Tritrinal* (TNT 2 parts & TNN 1 or 2 parts)(Ref 18,p Ger 209); *Unterwassersprengstoffe*(Ref 18,p Ger 212 -13)

*Note*: Many other composite Ger expls are listed in Ref 18

**Italy**: *Albite*(see Vol 1,p A120-L); *ANS*(see Vol 1, p A457-R); *Cheddites*(such as K chlorate 80, MNN 12 & castor oil 8%; Amm chlorate 82, DNT 13 & castor oil 5%; Na chlorate 75.0, MNT 23.2 & collod cotton 1.8%); *Cremonite*(AN 48.8 & Amm picrate 51.2%); *Cyclonite-AN-Wax Military Explosive*(RDX 22.0, AN 73.4 & wax 4.6%); *Cyclonite-Wax Military Explosive*(RDX 95 & wax, dyed red 5%); *Dinamiti* (Dynamites; many compns are known); *Dinamon*(AN 69, K chlorate 8, TNT 20 & Al 3%); *Dinitronaphthalene-Containing Explosives*(MST or Nougat,

Schneiderite and Siperite); *Dinitrotoluene-Containing Explosives* (such as DNT 19, collod cotton 1, Na chlorate 59 & PETN 21% or DNT 17, TNT 3.5, PETN 18, collod cotton 0.5, Amm perchlorate 36, & Na nitrate 25%); *Echo or Escho* (AN 62, Al 25, fat 7.5 & N 5.5%); *Esplosivo da guerra,* listed in CA **45**1770(1951) (TNT 30-90, PETN 65-5 and Al powder 5-30%; part of the TNT may be substituted by DNN); *Esplosivo da guerra,* listed in CA **44**, 6130(1950) (RDX 75-90 & Al powder 25-10%); *Esplosivo da mina,* listed in CA **45**,1709(1950) (RDX or PETN 75 & nitro-iso-butylglycerintriacetate 25%); *Esplosivo da mina,* listed in CA **45**,3160(1951) [TNT (of which up to 50% may be substituted by DNN) 30-9, RDX 65-5 & Al powder 5-30%]; *Esplosivo plastico,* listed in CA **43**,7688(1949) (RDX 85-89, petrolatum 10-12, thiocol 0.5-2 & glycerophthalic resin 0.5-2%); *Filler FNP* (AN 75, PETN 20 & wax 5%); *Filler for 500-kg Time Bomb* (PETN 65 & pentaerythritol-tetraacetate 35%); *FNP* (see Filler FNP); *GDI, GDII, GD2, GDIM, GEO & GEOM* are gelatinized mining expls contg NG; *Hidrolita* (mixt of RDX or PETN with AN, paraffin & 5-7% water); *Imperialite* (AN 85-90 & Al scales 15-10%); *MABT* (mixt of PA, TNT & DNPh), *MAT* (PA 60 & TNT 40%); *MBT* (PA 60 & DNPh 40%); *MNDT* (see under Siperite); *MST* (see Nougat); *Nitramite or Avigliana 3* (see Vol 1,p A516-R); *Nitronaftita* (RDX 75-80 & MNN 25-20%); *Nougat or MST* (AN 50, TNT 43 & DNN 7%); *PAM & PANA* (expl mixts based on PETN); *PETN Explosives* (mixts of PETN with wax, TNT, DNT, NG, AN, PETA, etc); *Piombite* (Pb nitrate 76, TNN 16, ca silicide 5 & vaseline 3%); *PNP* (AN 75, PETN 20 & wax 5%); *Sabulites* (mixts of AN with Ca silicide and TNT or TNN); *Schneiderite* (AN 87.5 & DNN 12.5%); *Siperite or Syperite* (AN 72.8, DNN 10.5 & TNT 16.7%); *Solfite* (AN 83-8 & S 17-12%); *Stabilites* (mixts of NG, TNAns & NG); *Toluolammonal* (AN 47, TNT 30, Al 20 & carbon 3%); *Tritolita or Tritolol* (mixts of TNT with RDX in various propns); *Tritolital* (TNT 60, RDX 20 & Al 20%); *Tritolol* (see Tritolita); *Umbrites* (NG 45.1 or 48,4, AN 41.4 or 37.3 & ferrosilicon 13.5 or 14.3%); *Vibrite* (AN 78, TNN 8 & Ca silicide 14%); *Victorite* [PA 53.7, K(Na or Ba) nitrate 4.9, K chlorate 39.0 & carbon 2.4%) (Refs 9b, 14a, 15a and other sources)

**Japan:** *A(ko)* (see Vol 1,p A119-L); *Ammonarā* (same as Ammonal); *Ammonyaku* (see Vol 1,p A383-L); *Anbenyaku or Shōbenyaku* (see Vol 1,p A401-R); *Angayaku* (see Vol 1,p A402-R); *B4* (same as Type 2 Explosive); *Chanayaku* (TNT 50 & RDX 50%); *"E"* (TNAns 60 & AN 40%); *Ennayaku* (K chlorate 80, MNT 15 & castor oil 5%); $H_2$-*Kongo* (see Type 98$H_2$ Explosive); *Haensosan-bakuyaku* (see under Type 88 Explosives); *Haishokuyaku No 1* (Amm perchlorate 76.9, RDX 17.0, paraffin 4.8 & Si carbide 1.3%); *Haishokuyaku No 2* (Amm perchlorate 48, GuN 20, RDX 25, paraffin 5 & graphite 2%); *Hexamit* [*see* A(ko), also called Otsu-B or Type A Explosive]; *Karritto* (see under Type 88 Explosives); *Ko* (see under Type 88); *Koshitsu or Shouyaku-koshitsu* (RDX 80 or 85 & oil 20 or 15%); *Mk 2* (see Nigotanyaku Mk 2); *Nigotanyaku Mk 2* (TNT 40-70 & RDX 60-30%); *Onayaku* (PA 50 or 80 & DNN 50 or 20%); *Oshitsuyaku* (RDX 80 & vegetable oil 20%); *Oshiyaku* (PA 90 & wax 10%); *Otsu-B* [*see* A(ko)]; *Pentoriru* (PETN 50 & TNT 50%); *Seigata* (see Type 97 Explosive); *Shoanbakuyaku* (AN 79, DNN 10, NaCl 10 & sawdust 1%); *Shoayaku* (mixts of AN with DNN, TNT, GuN, NaCl, woodmeal, etc); *Shobenyaku* of Nanman Arsenal (see Anbenyaku in Vol 1,p A401-R); *Shobenyaku* of Tama Factory (mixt of DNB, Tetryl & An); *Shoeiyaku Explosives* (PETN 91.5 & wax 8.5%; PETN 58 & RDX 42%) (see also Pentoriru); *Shonayaku or Shon-ō-yaku* (AN 90 & DNN 10%); *Shotoyaku* (AN 50 & TNT 50%); *Tanayaku Explosives* (RDX 92 or 95 & wax 8 or 5%; RDX 83 & PETN 17%) (see also Angayaku, Koshitsu, Nigotanyaku and Type 94 Explosive); *Tanōyaku* (RDX 55 or 60, TNT 38 or 30 & Tetryl 7 or 10%); *Torpex-Type Explosive* (AN 43.2, GuN 28.8, RDX 8.0 & Al 20.0%); *Type 1 Explosive* (Amm picrate 81, Al 16, heavy oil 1 & woodpulp 2%); *Type 1, Mk 5, P5* (Amm picrate 86, ferrosilicon 11, heavy oil 1 & woodpulp 2%); *Type 2(B4)* (TNAns 60 or 70 & Al powder 40 or 30%); *Type 88* (Navy) *or Karritto* (Army) (AN 66, Si carbide 16, woodpulp 16 & petroleum 6%); *Type 88(Ko) or Haensosan-bakuyaku* (Amm perchlorate 75, ferrosilicon 16, woodpulp 6 & heavy oil 3%); *Type 92* (Navy) (means straight TNT as well as the mixt of TNT 66 & Al powder 34%); *Type 94M* (Navy) (TNAns 60 & RDX 40%); *Type 97H* (Navy) (TNT 60 & HNDPhA 40%); *Type 98$H_2$ Kongo* (Navy & Army) (TNAns 70 & HNDPhA 30%); *Type A* see A(ko), vol 1,p A119-L) (Ref 8a and other sources)

**Russia:** *Almatrites* (see Vol 1,p A140-L); *Amatols* ( (such as AN 80 & TNT 20% and AN 86.8 & TNT 13.2%); *Ammokcil or Ammoksil* (see Vol 1,p A286-R); *Ammonals* (such as AN 82, TNT 12 & Al powder 6%); *Ammonits* (such as AN 77.6, TNT 18.4 & woodmeal 4%); *Ammonit-Goudronit* (see Vol 1,p A310-L); *Ammonpek* (see Vol 1,p A382-L); *Ammontol or Russkaya Smes'* (see Vol 1,p A383-L); *Baronal-Type Explosive* (Ba nitrate 38.9, Al powder 46.1, TNT 14.7 & sulfur 0.3%); *Bellites* (see Vol 2); *Dinamony* (such as paraffined AN 89-90 &

fuels, such as peat, 11-10%); *Dinitrobenzene-Containing Explosives* (such as Bellites and K-1 Splav -see under Benzene, Dinitro); *Dinitronaphthalene -Containing Explosives* (such as TNT 92 & DNN 8%; AN 87.5 & DNN 12.5%, Frantsuzskaya Smes', K-2 Splav, Russkii Splav and Schneiderite-Type Explosives); *Fielder Explosives* (mixts of 80/20 -MNB/turpentine with K chlorate & K permanganate); *Frantsuzskaya Smes'* (PA 80 & DNN 20%); *Gheksogen Explosives* (such as RDX 71.9, TNT 16.4 & Tetryl 11.7%; RDX 75.1, Al 20.8 & binder 4.1% and RDX 53 & TNT 47%); *K-1 Splav* (see under Benzene, Dinitro); *K-2 Splav* (TNT 80 & DNN 20%); *L-Splav* (TNT 95 & TNX 5%); *Melinit Explosives* (such as Russkii Splav); *Russkii Splav* (PA 51.5 & DNN 48.5%); *Schneiderite-Type Explosives* (such as AN 87.5 & DNN 12.5; AN 88 & TNN 12% and AN 82 & TNN 18%); *Tetryl Explosives* (such as Tetryl 57 & TNT 43%); *Trinitronaphthalene-Containing Explosives* (such as Schneiderite-Type Explosives); *Trinitrotoluene Explosives* (such as TNT 50-80 & RDX 50-20% and RDX 71.9, TNT 16.4 & Tetryl 11.7%) (Refs 9a, 12c & 13b); *Zhirov Explosives* [see N.F.Zhirov,RusP's 4283 & 4(1927); CA **22**,4821(1928)]

**Sweden:** *Ammongelatine* (see Vol 1,p A295-R of this Encyclopedia); *Ammoniakkrut* (see Vol 1,p A307-R); *Ammonium Nitrate Dynamites or Extra Dynamites* are probably similar to those described in Vol 1,p A355; *Black Powder* ($KNO_3$ 74-78, charcoal 12-15 & S 10-12%) (Ref 19,p 190); *Blastines* (see this volume); *Bofors Plastic Explosive* (see this volume); *Bonites* (see this volume); *Dynamites* (many compns are manufd in Sweden by AB Bofors Nobelkrut, Nitroglycerin AB, AB Norma Projektilfabrik, AB Nora Tändröfsfabrik, AB Svenska Krutfaktorierna and probably by other plants); *Gelatin Dynamites* (see under Dynamites); *Hexotols*, (military expls RDX/TNT-60/40 or 50/50 manufd by AB Bofors Nobelkrut(Ref 19,p 201); *Hexotonals* (military expls RDX/TNT/Al/Wax-40/44/15/1 or 40/44/15/5 manufd by AB Bofors Nobelkrut; another compn is RDX/TNT/Al/-30/50/20 with 1% wax and 1.5% carbon black added)(Ref 19,p 203); *Nauckhoff's Explosive* (Compn patented before WWI cont $NH_4ClO_4$ 43, $NH_4NO_3$ 26 and 31% of soln prepd by dissolving 4ps of collodion cotton in 96ps of liq TNT (Ref 1a, pp 247 & 681); *Novit* (Underwater expl of WWI contained (TNT 50 & HNDPhA 50% and of WWII: TNT 55.7, HNDPhA 27.9 & Al 16.4%) (Ref 4b,p 294; Ref 5c,pp 38 & 41; Ref 9b,p 107); *Territ* (Blasting plastic expl patented before WWI by AB Nitroglycerin: $NH_4ClO_4$ 43.0, DNT & TNT 27.8, $NaNO_3$ 28.0 & collodion cotton 1.2%) (Ref 3b,p 135 and Ref 4b,p 316)

**Switzerland:** *Aldorfit* (see Vol 1,p A123-R); *Ammonpentrinit* (see Vol 1,p 382-L); *Gamsit or Gelatine -Gamsit* (NG 21, NGc 5, collod cotton 1.6, woodmeal 0.4, liq DNT 12 & AN 60%); *Gelatine-Aldorfit* (NG with or w/o NGc 22, collod cotton 1.5, liq DNT with TNT 13 & AN 63.5%); *Gelatine-Cheddit* (Na chlorate 79, coated with a liq mixt of castor oil 5, DNT 2 & TNT 14 preheated to 40°); *Gelatine-Gamsit)* (See Gamsit); *Gelatine-Pentrinit* (mixt of PETN, NG & collod cotton, such as PETN 50, NG 46 & collod cotton 4%); *Gelatine-Telsit* (NG with or w/o NGc 22, collod cotton 1.5, DNT 21 & AN 55.5%); *Hexonit* (such as RDX 20-50 & NG 80-50% or RDX 50, NG 46 & collod cotton 4%); *Pentastit* 93/7 (PETN 93, phlegmatized with 7% pentaerythritol-tetrastearate, with or w/o 20% Al added); *Pentastit* 96.5/3.5 (PETN 96.5 & PETS 3.5% with or w/o 3.5% Al added); *Pentrinit* (mixt of PETN with not less than 20% NG); *Pentro or Pentryl* (mixts of PETN & TNT with or w/o Al powder); *Plastit* (a plastic military expl based on PETN and manufd by Schweiz-Sprengstoff-Fabrik AG; its compn has not been revealed); *Simplonit* (Gamist with 10-15% Al added); *Telsit* (see Gelatine-Telsit); *Telsit-Gamsit* (same compn as Gamsit)[Dr A.Stettbacher, Zürich, private communication(1954) and other sources]

**US and Great Britain:** *Alumatol* (see Vol 1,p A141 -R); *Aluminized Explosives* (see Vol 1,p A146-L); *Amatol* (see Vol 1,p A158-L); *Ammonal* (see Vol 1, p A287-L); *Baratol* (see Vol 2); *Baronal* (see Vol 2); *Boronite* (see Vol 2); *Compositions* A,B & C (see Vol 2); *Cyclotols* (see Vol 2); *DBX* (TNT 40, RDX 21, AN 21 & Al 18%); *Ednatols* (EDNA 50-60 & TNT 50-40%); *HBX* (TNT 38, RDX 40, Al 17 & wax 5%); *Minex* (TNT 40, RDX 5-15, Al 20 & Amm carbonate 35-15%); *Minols* (TNT 40 or 43, AN 40 or 37 & Al 20%); *Octol* (HMX 77 & TNT 23%) (Ref 20); *Pentolites* (PETN 10-75 & TNT 90-25%); *Pentonal* (PETN 40, TNT 40 & Al 20%); *PEP-3* (PETN 86 & oil 14%); *Picratol* (PA 52 & TNT 48%); *PIPE* (PETN 81 & oil 19%); *PTX-1* (TNT 14, RDX 21 & Tetryl 65); *PTX -2* (TNT 28.8, RDX 43.2 & PETN 28%); *PTX-3* (TNT 27,Tetryl 18 & EDNA 55%); *PTX-4* (TNT 31.5, PETN 13.5 & EDNA 55%); *RIPE* (RDX 85 & oil 15%); *Shellite* (PA 50 & DNPh 50%); *Sodatol* (Na nitrate 50 & TNT 50%); *Tetratols* (Tetryl 40-80 & TNT 60-20%); *Torpex* (TNT 37 or 40.2, RDX 45 or 41.5 & Al 18%); *Tridite* (PA 80 & DNPh 20%); *Trimonite* (PA 90 & MNN 10%); *Tritonal 80/20* (TNT 80 & Al 20%); *Tritonal D-2* (80/20 Tritonal 95 &D2 -Wax 5%); *UWE* (same as Tritonal 80/20)

*Refs*: 1)M.Giua,Gazz **45 I**, 352-8, 557-66(1915) &

CA **10**,598,1775(1916)(Binary mixts of nitro derivs of toluene and benzene and their eutectics) 1a)Colver(1918),247 & 681 1b)Barnett(1919),112 1c)A.Wogrinz & P Vâri,SS **14**,249-51 & 267-70(1919) & CA **14**,3530(1920)(Equilibrium diagrams of binary mixts of PA, TNT, DNT & MNN) 2)C.A.Taylor & W.H.Rinkenbach,JIEC **15**,73-7(1923)(Estimation of the proportions of TNT & Tetryl from freezing point curves) 3)Ibid **15**,795-6(1923)(The freezing point-solubility diagram of the system TNT-Picric Acid) 3a)Ibid **15**,1070-3(1923)(The freezing point -solubility diagram of the system Tetryl-Picric Acid) 3b)Naoûm, Expls(1927),135 4)Naoûm, NG(1928), 11,261 & 324 4a)Molina(1930),340 4b)Stettbacher (1933),294,309-10 & 316 4c)M.Giua & G.Guastalla, Chim & Ind **29**,64T(1933)(Study of binary systems of Centralite with p-MNT; 2,4-DNT, 2,4,6-TNT; PA and Bromo-2,4-dinitrophenol) 4d)T.Urbański et al, RocznikiChem **13**,399-434(1933) & C A **28**,27(1934); Ibid **14**,239-45, 925-40(1934) & CA **29**,6129(1935); Ibid **15**,191-7(1935) & CA **30**,2834(1936); Ibid **16**, 353-65(1936) & CA **31**,2502(1936); **17**,585-90(1937) & CA **32**,1556(1938)(Thermal analysis of various mixts contg nitrates, nitric acid esters and nitro compds) 5)Thorpe **4**,(1940),464 5a)Davis(1943), 353-4 & 367(Sprengel Expls and N2TN, NDNT, NT, NTN & NX expls) 5b)Bebie(1943),35 & 73 5c)A.Stettbacher, Protar **9**,38 & 41(1943) 6)W.R. Tomlinson,Jr,PATR **1360**(1943); Ibid **1379**(1944); Ibid **1402**(1944); Ibid **1414**(1944); **1429**(1944) & Ibid **1452**(1944)(Properties of ternary mixts of HE's) 7)A.J.Phillips,PATR **1445**(1944)(Properties of ternary mixts of HE's) 8)H.A.Aaronson, PATR **1469**(1944)(Properties of ternary mixts of HE's) 8a)Anon, "Handbook of Japanese Explosive Ordnance", OpNav **30-3M**(1945) 9)L.H.Eriksen, PATR **1506**(1945) & Ibid **1623**(1946)(Properties of ternary mixts of HE's) 9a)Shilling(1946),79-85, 90-2,95,97-9,144-7 & 240 9b)All&EnExpls(1946), 107 & 134 10)A.N.Campbell & E.J.Pritchard, CanadJRes **25B**,183-97(1947) & CA **41**,4647(1947) (Study of binary mixts PA-2,4-DNPh, TNT-DNPh and ternary mixt of PA-DNPh-TNT) 11)A.N.Campbell et al,CanadJRes **25B**,211-15(1947) & CA **41**, 7220(1947)(Study of binary and ternary eutectics consisting of PA, DNPh & Picramide) 12)A.N. Campbell & N.A.Kushnarov,CanJRes **25B**,216-27 (1947) & CA **41**,7218(1947)(Study of binary mixts of TNT-RDX, NENO-TNT and m-DNB-NENO) 12a)H.Ficheroulle,MP **30**,98-100(1948) & CA **45**, 8249(1951)(Studies of binary mixts of ethylenedinitramine, Amm ethylenedinitramate with AN and ethylenediamine nitrate showed that they are more sensitive and more expensive than the Fr std expl *Schneiderite*. For this reason the above mixts are not recommended for filling projs) 12b)Stettbacher (1948),83-5 12c)Blinov **1**(1948),17-20 13)G. Desseigne,MP **30**,127-37(1948)(Study of binary mixts of PETN with m-DNB, DNAns & DNPh) 13a)Blinov **2**(1949),64-5 13b)L.Médard,MP **32**, 213-16 & 223(1950)[Description of *Explosifs à nitratês* and *Explosifs nitratês à l'aluminium* developed in France beginning in 1935 and then after WWII and approved by CSE(Commission des Substances Explosives). These expls consist of AN, a nitro-compd(such as DNN, TNT, pentolite, etc) with or w/o Al powder. For instance, the expl *63-CSE-1949* consists of AN 67, TNT 10 & Al 21% and its CUP(power by the Fr lead block expansion method) is 147(PA=100)] 14)L.F.Audrieth & D.D. Sager,USP 2,482,089-91(1949) & CA **44**,839-40 (1950) [The three component expls: a)TNT/Tetryl /RDX b)Tetryl/TNT/EDNA and c)PETN/TNT /EDNA are characterized by their superior expl props, higher d, etc and for these reasons they are recommended for use in shells, bombs and mines]. 14a)Giua,Dizionario **2**(1951),165 15)Kirk & Othmer **6**(1951),19 & 56(Binary expls are described under Explosives) 15a)Belgrano(1952),118-22, 163.180-1,286 & tables 16)M.Thomas,MP **36**,133 -62(1952) & CA **49**,16435-6(1955) [Discussion of methods of separating components of binary mixts of nitrated derivs or nitrates by a solvent. From the amt of solvent just insufficient to dissolve a known wt of sample and the additional amt required to effect soln, the identity of the sample was detd. This was verified by addnl tests, such as mp, cryst form and colors obtd in acet soln with NaOH or $NH_3$. The method was applied to the following eight mixts: a)PETN/DNB b)PETN/TNT c)PETN/DNN d)RDX/DNB e)RDX/TNT f) HNDPhA/TNT g)Tetryl/TNT h)NGu/TNT] 17)K.Yamasue et al,JapP 2097('54) & CA **49**,2076 (1955)(A binary expl prepd by nitrating a mixt of 30% naphthalene & 70% toluene with 2.5 times its wt of 50/50 mixed nitric-sulfuric acid at 130°, rendered an expl with N 16.9% and mp 60° suitable for use in dynamites) 18)PATR **2510**(PB No 161270)(1958),pp Ger 4,5,6,30,43-4,46-8,88,114, 122,128,132,170,203,209 & 212-3 19)Anon,"Analytical Methods for Powders and Explosives",AB Bofors Nobelkrut,Sweden(1958) 20)D.Price,Chem Revs **59**,814-15(1959)

**Binder or Agglutinant** is a material, such as asphalt or bitumen, dextrin, starch, flour, glue, fossil gums, gelatin, milk sugar, petrolatum, resins, shellac, stearin, paraffin wax, sugar, syn-

thetic org plastics, NC, etc, used to hold solid substances together in a plastic mass. Binders are used in expls, proplnts and pyrotechnic compns. Most binders serve at the same time as fuels (see also Adhesives in Vol 1,p A102-R and under Bonding in Vol 2)
*Refs*: 1)Hackh's(1944),127 2)H.A.Bruson & G.B. Butler,USP 2400806(1946) & CA **40**,4526(1946) (Highly nitrated, vigorously combustible synthetic resin prepd by condensing TNT with HCHO and $NH_3$ or a primary amine capable of forming a MeOH deriv, may be used as a binding material in expl compns) 3)H.Zenftman & A.McLean,USP 2527420(1951) & CA **46**,2300(1952)(Nitropolystyrenes contg 9.3 to 14.4% N are recommended as binders for expl compns in lieu of NC) 4)Kirk & Othmer **11**(1953),334 (Binders in commercial pyrotechnic compns and in rockets) 5)Bjorksten Research Laboratories,Inc, "Polyesters and Their Application",Reinhold,NY (1956),21-34
*Addnl Refs on Binders*(not used as sources of info:
a)Frankford Arsenal Rept **R-445**(1943)(Stability of cellulose-alginate-glue binder for FA70 and FA-90A primary compns) b)S.Helf,PATR **1750**(1949) (Tests of expl binder compds submitted by ADL) (conf) c)H.J.Eppig & J.D.Strachan, PATR **1801** (1950)(Self-hardening pyrotechnic compns) d)Purchase Description **PA-PD-124** (1953), 4-6(Detn of binder-lubricant content in RDX) e)P.L.Nichols, Jr, et al,Caltech Progress Rept No **20-188**(1953) (Prepn of nitric ester plasticizers and resin intermediates for composite propellant resin binders for AN propellants) f)Ibid, No **20-197**(1953)(The use of epoxide resin binders for AN propellants) g)SFAL Rept No 54-FFI-71,PicArsn,Dover,NJ(1954) (Investgn of binders for Pelleting Type III, Class A,Photoflash Powder)(conf) h)F.H.Doe, ERDE TechMemo **7/M/55**(1955)(Plastic proplnt based on polyisobutene as binder) i)E.E.Mason et al,Nav Ord Rept **5461**(1957)(Preliminary investgn of castable perchlorate systems and binders for ammonium perchlorate)(conf) j)R.L.Wagner,K.G.Sheffield & D.E.Seeger,EDS SFAL Rept No **60**,PicArsn,Dover, NJ(1960)(Binder for RDX used in M47 Detonator consisting of 50/50 Ca resinate/Graphite) k)B. Jackson,S.M.Kaye & G.Weingarten,FREL Tech Note **40**,PicArsn,Dover,NJ(1960)(Resins other than Laminac 4116 as binders in pyrotechnic compns) l)US Military Specification MIL-B-10854(NC-comphor binder for pyrotechnic compns)

**Binding Energy.** See under Atomic(or Nuclear) Energy; Vol 1,p A500-R

**Bindone orAnhydrobisindandione**(called Anhydro-bis-[$\alpha.\gamma$-diketohydrinden] and other names in Ger), $C_{18}H_{10}O_3$, microscopic tablets, mp 206-8°(dec). Prepn & props are given in Ref 1. Vanags(Ref 2) proposed to utilize the prop of bindone to give characteristic colors with primary amines, for testing nitrocompds by first reducing them to amines (by means of Zn+AcOH) and then adding bindone. The test is not specific, however, for nitrocompds but applies also to nitroso, azoxy- and hydrazo-compds
*Refs*: 1)Beil **7**,876,(484) & [839] 2)G.Vanags, ZAnalChem **126**,21-35(1943) & CA **37**,6593(1943)

**Binitro-.**Same as Dinitro-. See under corresponding parent compounds

**Biochemical or Biological Oxidation.** See Bio-oxidation

**Biological, Bacteriological or Germ Warfare.** See under Chemical, Biological and Radiological(CBR) Warfare

**Biological Oxidation.** See Bio-oxidation

**Bio-oxidation, Biological Oxidation or Biochemical Oxidation** is a method for disposal of organic process water-borne wastes by the action of living organisms. Techniques for bio-oxidation may be divided into two general categories. The oldest method is to pass the wastes through a stationary biological bed, or *trickling filter*. The second method (first proposed during the period of 1910-1920) is to pass the biological growths through the wastes. This process is called *activated sludge*. Both of these processes are described in the Ref listed below

It must be noted that during WWII nearly all US expl and ammo plants used bio-oxidation for disposal of some of their organic wastes. This did not include TNT and some other expls for which no effective bacteria was found(See also under Waste Disposal)
*Ref*: W.W.Eckenfelder,Jr & T.L.More, "Bio-Oxidation", ChemEngrg **1955**(Sept), 189-202(22 refs)

**Bioxide d'hydrogène.** Fr for Hydrogen Peroxide

**BIP.** A cast double-base proplnt developed at ABL. Its compn & props are given in Propellant Manual, SPIA/M2(1959),Unit No 502

**Biphenic or Diphenic Acid** (Biphenyl-2,2'-dicarbox-

ylic Acid or Bibenzoic Acid) [Diphensäure; Diphenyl-dicarbonsäure-(2.2') in Ger]. See under Biphenyldicarboxylic Acids

**Biphenol and Derivatives**

*Biphenol, Dihydroxybiphenyl or Diphenol* (called Dioxy-diphenyl in Ger), $HO.C_6H_4.C_6H_4.OH$. Several derivs are described in Beil **6**,989,990, 991,993(484,485) & [960,961,962]

*Mononitrobiphenol*, $C_{12}H_9NO_4$ -not found in Beil

*Dinitrobiphenol*, $C_{12}H_8N_2O_6$. Several isomers are described in Beil **6**,990,992,993

*Trinitrobiphenol*, $C_{12}H_7N_3O_8$ -not found in Beil

**Tetranitrobiphenol**, $C_{12}H_6N_4O_{10}$, mw 366.20, N 15.30%. The following isomers are described in the literature:

*3,5,3',5'-Tetranitro-2,2'-biphenol or 2,2'-Dihydroxy-3,5,3',5'-biphenyl*, $(O_2N)_2(OH)C_6H_2.C_6H_2(OH)(NO_2)_2$, grn-yel ndls (from dil AcOH, mp 248-9°; easily sol in benz or AcOH; diffc sol in alc or ether. Can be prepd by nitration of 2,2'-biphenol or by other methods. It seems to be dimorphous; the 2nd form, prepd as described in Ref 2, decrepitated at 160°. Its expl props were not detd

*Refs*: 1)Beil **6**,990 & [960] 2)J.van Alpen,Rec **51**, 179-80(1932) & CA **26**,1273(1932)

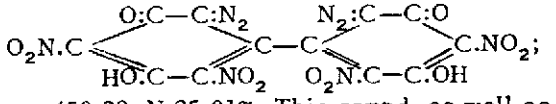
*4,6,4',6'-Tetranitro-3,3'-biphenol*, lt yel ndls(from dil AcOH), mp 208.5°; sol in hot w or alc; sol in acet, AcOH or benz; nearly insol in eth or chlf. Can be prepd by nitration of 3,3'-biphenol. Its expl props were not detd

*Refs*: 1)Beil **6**,(485) 2)W.Borsche,Ber **50**,830 (1917)

*3,5,3',5'-Tetranitro-4,4'-biphenol*, yel cryst(from AcOH), mp 223°. Can be prepd by nitration of 4,4'-biphenol or by other methods. Its expl props were not detd

*Refs*: 1)Beil **6**,992,(486) & [963] 2)G.van Romburgh,Rec **41**,40(1922) 3)H.Hart & W.J.Detroit, JACS **74**,5214-15(1952) & CA **48**,13664(1954) (The dissociation of 3,5,3',5'-tetranitro-4,4'-dihydroxybiphenyl in methanol)

**2,2'-Diazo-3,3'-dioxy-4,6,4',6'-tetranitro-m,m'-biphenol or Bis(2-diazo-3-oxy-4,6-dinitro)-m,m'-biphenol** (called sym-Tetranitro-dioxy-diphenol-quinone-tetrazide or Tetranitro-diresorcin-diazo-anhydride by von Herz),



mw 450.20, N 25.01%. This compd, as well as its salts, was claimed to have been prepd by von Herz but no method of prepn is given in the patent(Ref 2). Its K or Pb salts, or the compd itself, were proposed for use in initiators together with PETN as a base chge. The initiating power of this compd, or its salts, was claimed to be greater than that of LA

1)Beil- not found 2)E. von Herz,BritP 207563(1922); CA **18**, 1573-4(1924) & JSCI **43**, 451T(1924)

**Pentanitrobiphenol**, $C_{12}H_5N_5O_{12}$, mw 411.20, N 17.03%. The following isomer is described in the literature: *2,4,6,4',6'-Pentanitro-3,3'-biphenol*, $(O_2N)_2(OH)C_6H_2.C_6H(OH)(NO_2)_3$, yel grains(from dil alc), mp 248° (dec); sol in hot w or alc; sol in acet, AcOH or benz; nearly insol in eth or chlf. Was prepd by Borsche, together with 4,6,4' 6'-tetranitro-3,3'-biphenol, on nitration of 3,3'-biphenol. Its expl props were not investigated

*Refs*: 1)Beil **6**,(485) 2)W.Borsche,Ber **50**,830 (1917)

**Hexanitrobiphenol**, $C_{12}H_4N_6O_{14}$, mw 456.20, N 18.42%. The following isomer is described in the literature: *2,4,6,2',4',6'-Hexanitro-3,3'-biphenol or Bipicric Acid*, $(O_2N)_3(HO)C_6H.C_6H(OH)(NO_2)_3$, lt yel ndls (from benz), mp- stable up to 270°; expl at higher temp with evoln of flame; easily sol in w, alc, acet or AcOH; diffc sol in benz, eth or Can be prepd from 3,3'-biphenol by sulfonation with concd sulfuric acid followed by nitration with mixed nitric-sulfuric acid(Refs 1 & 2). It forms salts, such as *Potassium salt*, orn-yel mp 106°, expl 320°; *Ammonium salt*, $C_{12}H_4N_6O_{14}.2NH_3$, orn-yel, begins to dec at 275° and dec rapidly at 300-5°

*Refs*: 1)Beil **6**,(485) 2)W.Borsche,Ber **50**,832 (1917) 3)L.Mascarelli & B.Visintin,Gazz **62**, 358(1932) & CA **26**,4809(1932) 4)L.Mascarelli & D.Gatti,Industria Chimica **6**, No 11,7(1931) & CA **26**,5559(1932) 5)Blatt,OSRD **2014**(1944)-not listed

**Biphenyl and Derivatives**

*Biphenyl; Diphenyl; Diphenylyl or Phenylbenzene*, $C_6H_5.C_6H_5$; mw 154.20, col monocl crysts, mp 69-70°, bp 254.9°, d 0.992 at 73°/4°; $Q_c$ 1493kcal/mol, $Q_f$ 23.1kcal/mol(Ref 2a); insol in w; sol in alc or eth. Was first prepd in 1862 by Fittig. Many methods for its prepn are known (Refs 1 & 2) [See also CA's **43**,2979b(1949);**48**, 12175f(1954); **50**,1084c; 5753i; 12922e(1956)]. Biphenyl is one of the most thermally stable org compds. Chemically it resembles benz and can be chlorinated, nitrated, sulfonated and

hydrogenated. Its stereochemistry is discussed in Ref 1a. Biphenyl is used chiefly as a heat transfer medium and as the raw material for chlorinated biphenyls(Ref 2). It was also proposed as a fuel in turbojet type burners(Ref 3)
*Refs*: 1)Beil **5**,576,(271) & [479] 1a)R.Adams & H.C.Yuan,ChemRevs **12**,261-338(1933) 2)Kirk & Othmer **5**(1950),145-8 2a)G.S.Parks & L.M.Vaughan,JACS **73**,2380(1951) & CA **45**,10028 (1951) 3)J.W.Mullen & J.B.Fenn,BritP 709,035 (1954) & CA **48**,11032(1954) 4)J.M.Scarborough, North American Aviation, Inc, NAA-SR-4657 (1960)(IR spectra of biphenyl)(U)

*Azidobiphenyl*, $C_6H_5.C_6H_4.N_3$, mw 195.22, N 21.53%. Its ortho-deriv, col crysts, mp 49-50°, was prepd from 2-aminobiphenyl as described in Ref 2, under Procedure A
*Refs*: 1)Beil- not found 2)P.A.S.Smith & B.B. Brown,JACS **73**,2440(1951) & CA **46**,495(1952)

**Diazidobiphenyl**, $N_3.C_6H_4.C_6H_4.N_3$; mw 236.23, N 35.58%. The following isomers were found in the literature: *2,2'-Diazidobiphenyl*, tan ndls, mp 72.5-73.5°. Was prepd from 2,2'-dinitrobiphenyl as described in Ref 2. Its expl props were not detd(Ref 5) and *4,4'-Diazidobiphenyl* (called 4.4'-Bistriazo-diphenyl and "Tetrazobiphenylimid" in Ger), brownish crysts, mp 127° (Refs 1 & 4), mp 131°(Refs 2 & 3); decomp 165 -70°; expl on rapid heating or on contact with a drop of concd sulfuric acid(Refs 2 & 3). Can be prepd by treating diphenylbisdiazoniumperbromide with ammonia(Ref 1) or by other methods(Refs 2,3 & 4)
*Refs*: 1)Beil **5**,585 2)Beil **5**,[494] 3)F.D. Chattaway et al,JCS **125**,1984(1924) 4)H.Bretschneider & H.Rager,Monatsh **81**,970(1950) & CA **45**,7973(1951) 5)P.A.S.Smith et al,JACS **75**, 6337(1953) & CA **49**,7571(1955)

**Azidonitrobiphenyl**, $C_{12}H_8N_4O_2$, mw 240.22, N 23.33%. The isomers: *2-azido-2'-nitro*, mp 80.5-81.5°; *2-azido-3-nitro-*, mp 62.5-63.5°; *2'-azido-4-nitro*, mp 92.5-93.5°; and *2-azido -5-nitro-*, mp 86-7° are listed in Ref 2
*Refs*: 1)Beil- not found 2)P.A.S.Smith & B.B. Brown,JACS **73**,2440(1951) & CA **46**,495(1952)

**Azidodinitrobiphenyl**, $C_{12}H_7N_5O_4$, mw 285.22, N 24.56%. The isomers: *2-azido-3,5-dinitro-*, mp 118-19°; *2-azido-4,4'-dinitro-*, mp 177-8°, and *2-azido-5,4'-dinitro-*, mp 174-5° are listed in Ref 2, where their methods of prepn are given as Procedure B. Their expl props were not detd
*Refs*: 1)Beil- not found 2)P.A.S.Smith & B.B. Brown, JACS **73**,2440(1951) & CA **46**,495(1952)

*4-Nitrosobiphenyl*, $C_6H_5.C_6H_4.NO$, is listed in Beil **5**, [487]

**Mononitrobiphenyl**, $C_{12}H_9NO_2$, mw 199.20, N 7.03%. Several isomers are described in the literature. Its ortho isomer has been recommended(Ref 3) as a plasticizer for synthetic resins, cellulose esters & ethers and other products
*Refs*: 1)Beil **5**,582,583,(273) & [487] 2)J.Brull, Gazz **65**,19-28(1935) & CA **29**,3589(1935) 3)Monsanto Chemical Co,IEC **37**, No 12, p 78 (1945)(Props of tech grade o-nitrobiphenyl)

*Dinitrobiphenyl*, $C_{12}H_8N_2O_4$, mw 244.20, N 11.47%. Several isomers are described in the literature, none of them expl
*Refs*: 1)Beil **5**,583,584(273,274) & [490,491] 2)OrgSynthCollVol **2**(1943), 339

**3,3'-Dinitrobiphenyl-Lead Nitrate** [called *Di -(m-nitro-phenyl) Lead Nitrate* by McGill], $(O_2N.C_6H_4.C_6H_4.NO_2).Pb(NO_3)_2$, wh crysts, mp begins to turn brn at 210° & blackens at 245°; expl on rapid heating. Can be prepd by treating tetraphenyllead with nitric acid. It is an expl comparable in sensitivity to Tetryl and about 54% as powerful as TNT(by Ballistic Mortar Test). Its thermal stability is satisfactory but it is appreciably hygroscopic
*Refs*: 1)Beil- not found 2)R.McGill,OSRD**830** (1942),21

**Trinitrobiphenyl**, $C_{12}H_7N_3O_6$, mw 289.20, N 14.53%. The following isomers are described in the literature: *2,4,6-Trinitrobiphenyl*, $C_6H_5C_6H_2(NO_2)_3$, lt yel ndls(from alc), mp 130°. Was prepd by heating picrylchloride with iodobenzene and copper bronze at 190-200°(Ref 1 & 3) *2,4,2'-Trinitrobiphenyl*, $(O_2N)C_6H_4.C_6H_3(NO_2)_2$, lt yel prisms(from AcOH), mp 150-1°. Was obtained, together with 2,4,4'-trinitrobiphenyl, by heating 2,4- or 2,4' -dinitrobiphenyl with nitric acid(d 1.5) at 100° (Refs 1 & 3) *2,4,4'-Trinitrobiphenyl*, lt yel crysts(from AcOH or $HNO_3$), mp 175.5-176°. Was first prepd by treating biphenyl with ethylnitrate in concd sulfuric acid at -5°(Refs 1 & 2). Another method is the nitration of 2,4- or 2,4' -dinitrobiphenyl with nitric acid(d 1.5) at 100° (Refs 1,2 & 3) *2,4,3'-Trinitrobiphenyl*, crysts (from alc), mp 137-8°; was prepd by heating 2,-3'-dinitrobiphenyl with nitric acid(d 1.5) for 3 mins(Ref 5) *3,4,3'-Trinitrobiphenyl*, crysts (from acet+alc). mp 179-80°; was prepd by heating 3,3'-dinitrobiphenyl with nitric acid(d 1.5) for 1 hr(Ref 3) *3,3,4'-Trinitrobiphenyl*, cryts (from benz), mp 205-6°; was prepd by heating

3,4'-dinitrobiphenyl with nitric acid(d 1.5) for 1 hr(Ref 5) and *3,5,3'-Trinitrobiphenyl,* solid mp 173-4°; was prepd in small quantity by heating 3,5-dinitroiodobenzene with m-nitroiodobenzene & Cu powder for an hr at 270°(Ref 4). Expl props of trinitrobiphenyls were not detd

*Refs*: 1)Beil **5**,[493] 2)H.Raudnitz & H.Böhm, Ber **60B**,740-1(1927) & CA **21**,1981(1922) 3)H.C.Gull & E.E.Turner,JCS **1929**,495-8 & CA **23**, 2962(1929) 4)F.H.Case,JACS **64**,1852(1942) & CA **36**,5805(1942) 5)F.H.Case,JACS **64**,2225 (1942) & CA **36**, 6517(1942)

**Tetranitrobiphenyl**, $C_{12}H_6N_4O_8$, mw 334.20, N 16.77%. The following isomers were found in the literature:

*2,4,2',4'-Tetranitrobiphenyl,* $(O_2N)_2C_6H_3(NO_2)_2$, lt yel crysts(from benz), mp 163-6°; easily sol in AcOH or benz; diffc sol in alc or eth. Can be prepd by nitration of diphenyl(Refs 1 & 5), of 2,2'-dinitro-, of 2,4,2'- or 2,4,4'-trinitrobiphenyl, or by other methods(Refs 1 & 4). Its expl props were not detd

According to Ref 4, this compd is dimorphous with mp's 166° & 150-1°

*Refs*: 1)Beil **5**,585 & [494] 2)F.Ullmann & J.Bielecki,Ber **34**,2177(1901) 3)H.C.Gull & E.E.Turner,JCS **1929**,495 4)J.van Alphen,Rec **51**,456-7(1932) 5)E.H.Huntress,USP 1 870-627(1932) & CA **26**,5579(1932)

*2,4,3',4'-Tetranitrobiphenyl,* lt yel crysts(from methanol), mp 173°; can be prepd by treating 2,3'- or 3,4'-dinitrobiphenyl with mixed nitric -sulfuric acid. Its expl props were not detd

*Refs*: 1)Beil **5**, [494] 2)W.Blakey & H.A. Scarborough,JCS **1927**,3006 & CA **22**,955(1928)

*2,6,2',6'-Tetranitrobiphenyl*, yel ndls(from AcOH), mp 217-18°; was first prepd in small quantity by treating 2-chloro-1,3-dinitrobenzene with Cu pdr in boiling benz(Refs 1 & 2); can also be prepd by heating 1-bromo-2,6-dinitrobenzene with copper bronze for 2 hrs on an oil bath(Ref 3). Its expl props were not detd

*Refs*: 1)Beil **5**,(274) 2)W.Borsche & D.Rantscheff, Ann **379**,176(1911) 3)J.Hawkins & S.H.Tucker, JCS **1950**,3288 & CA **45**,6619(1951)

*3,4,3',4'-Tetranitrobiphenyl,* yel prisms, mp 186° (Refs 1 & 2); crysts(from alc+acet), mp 203-4° (Ref 3); easily sol in AcOH or benz; nearly insol in ligroin. Was first prepd by heating 1,2-dinitro -4-iodobenzene with copper bronze at 230-50° (Refs 1 & 2); can slao be prepd by nitration of 3,4,3',-trinitrobiphenyl with mixed nitric-sulfuric acid(Ref 3). Its expl props were not detd

*Refs*: 1)Beil **5**,585 2)F.Ullmann & J.Bielecki, Ber **34**,2179(1901) 3)F.H.Case,JACS **64**,2225 (1942) & CA **36**,6517(1942)

*3,5,3',5'-Tetranitrophenyl,* solid(from toluene), mp 228-9°; was prepd by heating with stirring a mixt of 3,5-dinitroiodobenzene with Cu pdr at 270° for 1½hrs. Its expl props were not detd

*Refs*: 1)Beil- not found 2)F.H.Case,JACS **64**, 1852(1942) & CA **36**,5805(1942)

*Pentanitrobiphenyl*, $C_{12}H_5N_5O_{10}$ – not found in Beil or CA thru 1956

**2,4,6,2',4',6'-Hexanitrobiphenyl,** $(O_2N)_3C_6H_2$ - $C_6H_2(NO_2)_3$, mw 424.20, N 19.81%, OB to $CO_2$ -52.8%; brn crysts with 0.5 $C_7H_8$(from toluene), mp 238° (Refs 1 & 2); yel -brn crysts(from AcOH), mp 242°(Ref 5); lt yel crysts with 0.5$C_7H_8$(from toluene); loses $C_7H_8$ at 140°(Ref 3); mp 263°(Ref 6); ignites above 320°; insol in w; sl sol in acet, alc, eth, hot benz, toluene or AcOH. HNBPh gives a yel color with concd sulfuric acid and red with alc to which a drop of ammonia water or aq caustic soda has been added. It is neutral, chemically unreactive toward metals and is reported to be non-poisonous(Refs 1,2 & 6). It can be compressed to d 1.61 at 2500 atms

HNBPh was first prepd in 1901(Ref 2) by boiling picryl chloride in MNB soln with Cu pdr for a short time. The solvent is necessary in order to moderate the reaction, for picrylchloride & Cu pdr expl when heated alone to ca 127°(Ref 6). It cannot be prepd by direct nitration of biphenyl; the highest nitrated product is 2,4,2',4'-tetranitrobiphenyl(Ref 6)

HNBPh is a powerful expl; its Trauzl test value is about 10% higher than for HNBPhA (Refs 6 & 7). It is more sensitive to impact than TNB and less sensitive than Tetryl(Ref 5). Jahn(Ref 4) patented the following expl mixt claimed to be suitable for loading torpedoes and mines: HNBPh 12, AN 80, NG 4 & flour 4%

*Refs*: 1)Beil **5**,585(274) & [494] 2)F.Ullman & J.Bielecki,Ber **34**,2179(1901) 3)Sprengstoff AG Carbonit,GerP 286736(1913) & CA **10**,1272(1916) and BripP 18333(1914) & CA **10**,392(1916) 4)C.R.Jahn,USP 1253691(1918) & CA **12**,767(1918) 5)C.F.van Duin,Rec **39**,686-7(1929) 5a)Pepin Lehalleur(1935),193 6)Davis(1943),158-9 7)Blatt,OSRD **2014**(1944) 8)Sax(1957)-not listed

**2,4,6,2',4',6'-Hexanitrobiphenyl Salts,** *The Lead salt,* $C_{12}H_2N_6O_{12}Pb$ and the *Mercury salt* $C_{12}H_2N_6O_{12}Hg$, were prepd and examined during WWII in the US and were found to be less powerful and brisant than PA

*Ref*: A.H.Blatt & F.C.Whitmore,OSRD **1085**

(1942),48

**Biphenyl-4-amine.** See under Aminobiphenyls; Vol 1,p A191-L

**Biphenylamine.** See Diphenylamine

**Biphenyl-bis(diazoniumhydroxide) and Derivatives**

**Biphenyl-bis(4,4'-diazoniumhydroxide)** [called Diphenyl-bis-diazoniumhydroxid-(4.4') or Tetrazodiphenyl in Ger], HO.N(:N).$C_6H_4$.$C_6H_4$.N(:N).OH; mw 242.23, N 23.13%; known only in the form of its salts, some of which are expl: *Antimony Chloride*, $C_{12}H_8(N.Cl)_2+5SbCl_3+HCl$; col ndls, mp expl violently; *Borofluoride*, $C_{12}H_8(N_2.BF_4)_2$; crysts(from w), mp dec ca 137-138°; *Lead Chloride*, $C_{12}H_8(N_2.Cl)_2+PbCl_4$; orn-yel crysts, mp expl ca 131°; *Nitrate*, $C_{12}H_8(N_2.O.NO_2)_2$; yel-wh ndls(from w by pptn with alc & eth), mp expl on heating; and *tetrachloroiodide*, $C_{12}H_8(N_2.ICl_4)_2$; yel-brn crysts, mp expl at 135-140°. Other props and methods of prepn of these and other salts are given in Beil **16**,515,(362) & [285]

**2-Nitrobiphenyl-bis(4,4'-diazoniumhydroxide)**, HO.N(:N).$C_6H_4$.$C_6H_3$.$(NO_2)$.N(:N).OH; mw 287.23, N 24.38%. Its *Antimony Chloride salt*, $C_{12}H_7NO_2(N_2.Cl)_2+2SbCl_3+2HCl$; yel crysts, dec on heating with w. Other props & method of prepn are given in the Refs

*Refs*: 1)Beil **16**,(362) 2)P.May, JCS **101** I,1035 (1912)

**Biphenylcarboxylic Acid and Derivatives**

*Biphenylcarboxylic or Phenylbenzoic Acid* (Carboxydiphenyl), $C_6H_5$.$C_6H_4$.COOH. Three isomers are known and described in Beil **9**,669,671(279, 280) & [463,464]

*Mononitrobiphenylcarboxylic Acid*, $C_{13}H_9NO_4$. Several isomers are described in Beil **9**,670

*Dinitrobiphenylcarboxylic Acid*, $C_{13}H_8N_2O_6$. Several isomers are described in Beil **9**,672 & [465]

*Trinitrobiphenylcarboxylic Acid*, $C_{13}H_7N_3O_8$, mw 333.21, N 12.61%- not found in Beil or in CA thru 1956

*Tetranitrobiphenylcarboxylic Acid*, $C_{13}H_6N_4O_{10}$, mw 378.21, N 14.82%- not found in Beil or in CA thru 1956

**Pentanitrobiphenylcarboxylic Acid**, $C_{13}H_5N_5O_{12}$, mw 423.21, N 16.53%. The following isomer is known: *2,4,6,2',4'-Pentanitrobiphenyl-3-carboxylic Acid; 2,4,6,2',4'-Pentanitro-3-carboxydiphenyl or 3-(2',4'-Dinitrophenyl)-2,4,6-trinitrobenzoic Acid*, $(O_2N)_2C_6H_3$.$C_6H(NO_2)_3$.COOH, wh crysts (from benz), mp 205-6°. Was prepd by treating in a salt-ice bath, with stirring, the 2,4,6,2',4'-pentanitro-3-methylbiphenyl with fuming nitric acid, followed by fuming sulfuric acid. The expl props of pentanitro-compd were not investigated

*Refs*: 1)Beil- not found 2)H.A.Stearns & R. Adams, JACS **52**,2070 & 2073(1930) & CA **24**,3005 (1930)

*Hexanitrobiphenylcarboxylic Acid*, $C_{13}H_4N_6O_{14}$- not found in Beil or in CA thru 1956

**Biphenyldiamine.** Same as Diaminobiphenyl

**Biphenyldiazomethane**, $(C_6H_5)_2C{:}N{:}N$, mw 194.23, N 14.42%, dk-red ndls(from petr ether), mp 29-30°, decomp explosively ca 115°; easily sol in most org solvents. Can be prepd by oxidation of benzophenonehydrazone with freshly pptd mercuric oxide in petr ether or by other methods

*Refs*: 1)Beil **7**,(226) & [358] 2)H.Staudinger et al, Ber **49**,1908 & 1932-3(1916) 3)M.Busch & R. Knoll, Ber **60**,2254(1927)

**Biphenyldiazoniumhydroxide**, $C_6H_5$.$C_6H_4$.N(:N).OH, exists only in the form of derivs. Some of them are described in Beil **16**, [283-4]

**Biphenyldiazonium Perchlorate.** See under Aminobiphenyls; Vol 1,p A191-L

**Biphenyldicarboxylic Acid and Derivatives**

*Biphenyldicarboxylic Acid*, $C_{14}H_{10}O_4$. Several isomers are known, of which the *2,2'-Biphenyldicarboxylic Acid, Biphenic or Diphenic Acid* (called Diphensäure in Ger),

HOOC.$C_6H_4$.$C_6H_4$.COOH,

seems to be of some industrial importance. Its prepn from phenanthrene is described in Ref 2

*Refs*: 1)Beil **9**,922,926,927,(401) & [655,663, 664,665] 2)W.F.O'Conner & E.J.Moriconi, IEC **45**,277-88(1953)

**Diazidobiphenyldicarboxylic Acid**, $C_{14}H_8N_6O_4$, MW 324.25, N 25.92%. The following isomer is described in the literature: *4,4'-Diazidobiphenyl-3,-3'-dicarboxylic Acid*, HOOC.$C_6H_3(N_3)$.$C_6H_3(N_3)$.COOH, grey-grn crysts decompg ca 165°; sol in alc or AcOH; v diffc sol in benz & ligroin. Was prepd from 4,4'-diaminobiphenyl-3,3'-dicarboxylic acid as described in Refs 1 & 2. Its expl props were not detd

*Refs*: 1)Beil **9**,927 2)C.Bülow & W.von Reden, Ber **31**,2578(1898)

*Mononitrobiphenyldicarboxylic Acid*, $C_{14}H_9NO_6$.

Several isomers are described in Beil **9**,925

*Dinitrobiphenyldicarboxylic Acid*, $C_{14}H_8N_2O_8$. several isomers are described in Beil **9**,925

*Trinitrobiphenyldicarboxylic Acid*, $C_{14}H_7N_3O_{10}$, mw 377.22, N 11.14%. One isomer, *4,6,4'-Trinitrodiphenyl-2,2'-dicarboxylic Acid* is described in Beil **9**,[662]

**Tetranitrobiphenyldicarboxylic Acid**, $C_{14}H_6N_4O_{12}$, mw 422.22, N 13.27%. The following isomers are described in the literature: *4,6,4',6'-Tetranitrobiphenyl-2,2'-dicarboxylic Acid*, $(O_2N)_2(HOOC)C_6H_2$-$C_6H_2(COOH)(NO_2)_2$, col crysts(from w), melting at 288-9° when heated slowly and decompg when heated rapidly; easily sol in alc AcOH or hot w; diffc sol in benz. Can be prepd by nitration of di- or trinitrobiphenyldicarboxylic acid(Refs 1 & 3). Method of prepn from methyl ester of 2-chloro-3,5-dinitrobenzoic acid is described in Ref 2(See also Ref 4); and *2,6,2',6'-Tetranitrobiphenyl-4,4'-dicarboxylic Acid*, $(O_2N)_2(HOOC).C_6H_2.C_6H_2$-$(COOH)(NO_2)_2$, crysts, mp 338-42°; was prepd by hydrolysis of methyl 2,6,2',6'-tetranitro-4,4'-diphenate as described in Ref 5. Their expl props were not investigated

*Refs*: 1)Beil **9**,926 & [662] 2)F.Ullmann,Ann **366**,88-9(1909) 3)G.H.Christis & J.Kenner,JCS **121**, 618-19(1922) & **123**,782(1923) 4)R.Kuhn & O.Albrecht,Ann **458**,221-2(1927) & CA **22**,413 (1928) 5)K.Mislow & R.Bolstad,JACS **77**,6712 (1955) & CA **50**,11990(1956)

*Pentanitrobiphenyldicarboxylic Acid*, $C_{14}H_5N_5O_{14}$-not found in Beil or in CA thru 1956

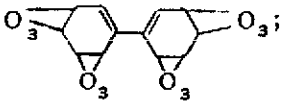
**Hexanitrobiphenyldicarboxylic Acid**, $C_{14}H_4N_6O_{16}$, mw 512.22, N 16.41%, OB to $CO_2$ -43.7%. The following isomer is known: *2,4,6,2',4',6'-Hexanitrobiphenyl-3,3'-dicarboxylic Acid or 2,4,6,2',4',6'-Hexanitro-3,3'-dicarboxydiphenyl*, $HOOC.(O_2N)_3C_6H.C_6H(NO_2)_3.COOH$, col ndls (from hot benz), rapidly turning yel in air; mp 292-3°. Was prepd by oxidation of 2,4,6,2',4',6'-hexanitro-3,3'-dimethylbiphenyl with a mixt of fuming $HNO_3$ & $H_2SO_4$ with $Na_2Cr_2O_7$ at a temp below 30°. Its expl props were not detd

*Refs*: 1)Beil- not found 2)L.H.Bock, W.W.Moyer & R.Adams, JACS **52**,2054-8(1930) & CA **24**,3004 (1930)

**p,p'-Bi(phenylene-azo-trinitromethane)**, $(O_2N)_3C.N{:}N.C_6H_4.C_6H_4.N{:}N.C(NO_2)_3$; mw 412.29, N 33.97%; pdr, very stable in air, mp-expl violently ca 112°. Was prepd by Quilico (in the course of investigation of reactions betw acetylene and fuming nitric acid) on treating Amm nitroformate and the diazonium salt of benzidine with an amt of AcONa sufficient to eliminate the mineral acid

Quilico considered the compd as the most interesting of all the expl compds obtained by him during his studies of the reactions between acetylene and fuming nitric acid. It is also listed in Vol 1,p A67-R as p,p'-Biphenylenebisazotrinitromethane

*Refs*: 1)Beil- not found 2)A.Quilico,Gazz,**62**, 912ff(1932) & CA **27** 1348(1933)(Not listed in CA Formula Index for 1920-46)

**Biphenyl Tetraozonide** (called Diphenyltetraozonid in Ger), $C_{12}H_{10}O_{12}$,  ; mw 314.20, O 50.92%; col crysts, very volatile; expl violently on heating. Can be prepd by treating biphenyl with ozone in chlf. This compd is stable in dil ethyl acet soln

*Refs*: 1)Beil **5**,579 & [482] 2)C.Harries & V. Weiss,Ann **347**(1905)

**Bipicric Acid.** See 2,4,6,2',4',6'-Hexanitrobiphenol under Biphenol and Derivatives

**Bipropellant.** A rocket proplnt consisting of two unmixed chemicals(usually liquid) fed into the combustion chamber separately. One of the chemicals is a fuel(such as alcohol, aniline, hydrazine, etc), while the other is an oxidizer(such as liq O, nitric acid, hydrogen peroxide or nitrogen tetroxide). The energy released on combustion of fuel operates a propulsive rocket unit

*Refs*: 1)Warren(1958),13-14 2)Rocket Encycl (1959), 43-4

**Bipropellant Rocket Engine** A rocket engine that burns a bipropellant in its combustion chamber. If a fuel ignites spontaneously on coming in contact with an oxidizer(*hypergollic propellant*) there is no need for any ignition devices

This engine is sometimes referred to as the *bifuel rocket engine*. This term is however, improper because the bifuel engine identifies an unusual device where two fuels are burned in a reaction with an oxidizer thereby consuming three liquids

*Ref*: Rocket Encycl (1959),43-5

## BIRESORCINOL AND DERIVATIVES

*Biresorcinol or Tetrahydroxybiphenyl* (called Diresorcin or Tetraoxy-diphenyl in Ger), $(HO)_2C_6H_3.C_6H_3(OH)_2$. Several iromers are described in Beil **6**,1163-4 & [1126,1129]

*Dinitrobiresorcinol*, $C_{12}H_8N_2O_8$. One isomer is described in Beil **6**,[1129]

**Tetranitrobiresorcinol**, $C_{12}H_6N_4O_{12}$; mw 398.20, N 14.07%. The isomer *3,5,3',5'-Tetranitro-2,6,2',6'-tetrahydroxy-biphenyl*, crysts, mp 268°; nearly insol in w; sl sol in alc; sol in ethor et acetate. Can be prepd by treating 4,6-dinitro-2-diazonium hydroxide with aq KOH, followed by an acid. Its expl props were not detd

*Refs*: 1)Beil **6**,1164 2)R.Benedikt & A.Hübl, Montash **2**,329(1881) & ChemZtr **52**,548(1881)

*Pentanitrobiresorcinol*, $C_{12}H_5N_5O_{14}$- not found in Beil or in CA thru 1956

**Hexanitrobiresorcinol**, $C_{12}H_4N_6O_{16}$; mw 488.20, N 17.22%, OB to $CO_2$ -32.8%. One isomer, known as *2,4,6,2',4',6'-Hexanitro-3,5,3',5'-tetrahydroxy-biphenyl*, consists of shiny yel crysts, explg ca 230° w/o melting(Ref 2); expln temp given in Ref 3 is 245°; very easily sol in w. Was first prepd in 1884(Ref 2) by heating biresorcinoltetracetate with fuming nitric acid; can also be prepd by treating biresorcinol with fuming nitric acid(Ref 3). Its power by the Trauzl test is ca 95% PA (Ref 6)

Its *Lead salt* was prepd and patented in 1923 for use in initiating compns (Ref 4). It is less sensitive to friction and impact than the parent compd, as was detd by Rathsburg(Ref 5)

*Refs*: 1)Beil **6**,1165,(574) & [1128] 2)R.Benedikt & P.Julius,Monatsh **5**,178(1884) 3)O.von Friedrichs,ChemZtr **1916** II,975 4)W.Friederich,ChemZtr **1923** IV,267 5)H.Rathsburg,ZAngewChem **41**, 1285(1928) 6)Blatt,OSRD **2014**(1944), under Nitro-compounds

**Birkeland-Eyde Process.** See under Nitrogen Fixation Processes

**Birth (Initiation) and Growth of Explosion in Solid and Liquid Explosives Initiated by Impact, Friction etc.** High-speed cameras reveal that when liq expls, such as NG or NGc, as well as many solid expls, such as TNT, PETN, Tetryl etc, are initiated by one of the usual methods, the expln or deton originates at one or several *hot spots*, contg either minute bubbles of gas(vapor) or particles of grit. In the case of gas, the expln is caused by the rise in temp due to the adiabatic compression of the gas, while in the case of grit, friction betw the particles of grit and the surrounding expls causes the temp to rise

The fact that the presence of gas pockets or of grit in expls causes increases in sensitivity of the expl has been known for a long time, but only recently(with the introduction of high-speed cameras) did it become possible to examine the phenomenon more closely

A series of tests was made in England and some tests were made in France

In regard to entrapped gases, it may be mentioned that Yoffe(Ref 6) confirmed the results of previous investigators and in addn has shown that even the adiabatic compression of the vapor of an expl helps the initiation

In regard to the influence of grit, Capp et al (Ref 7) claimed that sensitiveness to impact increases if grit of hardness greater than 4 is present while Bowden & Gurton(Ref 8) claim that only grit with mp higher than 400° increases the sensitiveness of expls such as PETN, while grits with mp's higher than 500° are required to increase the sensitiveness of LA, LSt and MF. The hardness of grit used in these tests varied betw 2 & 7 on the Moh scale

*Refs*: 1)M.Patry,Thesis(1933),NancyFrance 2)R.G.Vines & M.F.R.Mulcahy,Nature **157**,626 (1946) 3)R.G.Vines, Ibid **160**,400(1947) 4)F.P.Bowden et al, PrRoySoc **188A**,311(1947) 5)F.P.Bowden & O.A.Gurton,Nature **161**,348(1948) & CA **42**,3963(1948) 6)A.Yoffe,Ibid **161**,349 (1948) & CA **42**,3961(1948) 7)J.L.Capp et al, TrRoySoc, **241A**,197-296(1948) & CA **42**,7983 (1948) 8)F.P.Bowden & O.A.Gurton,Nature **162**, 654-5(1948) & CA **43**,1982(1949) 9)F.P.Bowden, & O.A.Gurton,PrRoySoc **198A**,35-72(1949) & CA **44**,2244(1950) 10)F.P.Bowden & A.D.Yoffe, "Initiation and Growth of Explosion in Liquids and Solids",Cambridge UnivPress(England)(1952)

## BIS COMPOUNDS

The latin prefix "bis" means twice or double as does the Latin prefix "bi". The Greek prefix "di" signifies two or double groups. In attempting to systematize org chem nomenclature, the prefix "di" is usually employed to denote the doubling of simple radicals or compds, inorg or org, attached to the same atom; for example, diazido, dinitro, dinitroso, etc; also *diphenylamine*, $(C_6H_5)_2NH$; *diethanolamine*, $(HO.CH_2.CH_2)_2NH$; and *diphenylmethane*, $(C_6H_5)_2CH_2$. "Bi" is used primarily to denote the doubling of a radical or molecule of the kind when united with the loss of hydrogen; for example, *bibenzyl*, $C_6H_5.CH_2.CH_2.C_6H_5$; *bimalonic acid*, $(HOOC)_2CH.CH(COOH)_2$ and *biphenyl*, $C_6H_5.C_6H_5$. The prefix "bis" is used like "di", but before complex radicals or expressions attached to a third atom or radical; for example, *bis(chloromethyl)*-$(ClCH_2-)_2$; *bisdimethyl-*

*amino-*, $[(CH_3)_2N-]_2$; and *3,5-bis(phenylacetyl)-benzonitrile*, $C_6H_5.CH_2.CO.C_6H_4(CN).OC.CH_2.C_6H_5$. "Bis" may also be applied to complex molecules made up of similar halves or compds; for example, *azobisformamidine*, $H_2N.C(:NH).N:N.C(:NH).NH_2$; and the cyclic compds, *bistetrazole*, $CHN_4CHN_4$, and *bistriazole*, $C_2H_2N_3$-$C_2H_2N_3$. There are some instances where common usage in the literature dictates the prefix which is adopted. For example, a compd commonly known as DINA is listed, by us, as Diethanolnitramine Dinitrate under Diethanolamine, while Bis(2-nitroxyethyl)-nitramine and Dinitroxyethylnitramine are given as alternate names. In general, in the naming and listing of "bis", "bi", add "di" compds, we will follow the system adopted by CA as the compds are listed in the latest CA Index. An alternate or second name may also be used when either can be applied without creating ambiguity

*Refs*: 1)Hackh's(1944),125,129 & 262 2)A.M. Patterson et al, "Nomenclature, Organic Compounds", CA **39**,5875(1945) 3)International Union of Pure and Applied Chemistry(IUPAC)"Definitive Rules for Nomenclature of Organic Chemistry", JACS **82**,5545(1960) 4)C.D.Hurd,"The General Philosophy of Organic Nomenclature",JChemEduc **38**,43(1961)

## LIST OF BIS COMPOUNDS

### Bis(allyloxymethyl)-propanediol and Derivatives

*2,2-Bis(allyloxymethyl)-1,3-propanediol or Diallylpentaerythritol,*

$HO.H_2C.C(CH_2.O.C_3H_5)(CH_2.O.C_3H_5).CH_2.OH$, mw 216.27, O 29.59%; liq, bp 120° at 1mm, d 1.046 at 20/20°, $n_D$ 1.4729 at 20°; was prepd by treating pentaerythritol in p-dioxane with allyl chloride(Ref 3)

*2,2-Bis(allyloxymethyl-1,3-propanediol Dinitrate,*

$O_2NO.CH_2.C(CH_2.O.CH_2.CH{:}CH_2)(CH_2.O.CH_2.CH{:}CH_2).CH_2.ONO_2$; mw 306.27, N 9.18%, liq, d 1.191, at 20/20°, $n_D$ 1.4688 at 20° (Ref 2); heat of combustion is given in conf Ref 2. Its prepn is described by Evans & Gallaghan

*Refs*: 1)Beil-not found 2)ADL Rept **4**(1952), 549(C) 3)Evans & J.A.Gallaghan,JACS **75**, 1249(1953) & CA **49**,3811(1955)

**1,3-(β-aminoethanol)-benzene.** Same as 1,3-Bis (β-hydroxyethylamino)-benzene

### Bis(aminoethyl)-amine and Derivatives

*Bis(β-aminoethyl)-amine; Di(β-aminoethyl)-amine; 1,4,7-Triazaheptane; Diethylenetriamine or DETA,* $H_2N.CH_2.CH_2.NH.CH_2.CH_2.NH_2$; mw 103.17, N 40.73%; strongly alk liq, bp 109° at 20mm. Other props and prepn are given in Ref 1

**Bis(β-nitraminoethyl)-amine; Di(β-nitraminoethyl)-amine; 1,7-Dinitro-1,4,7 triazaheptane or 1,7-Dinitrodiethylenetriamine,**

$O_2N.HN.CH_2.CH_2.NH.CH_2.CH_2.NH.NO_2$; mw 193.17, N 36.26%; micro-cryst ndls, mp 215-16°. Can be prepd from DETA as follows:

$H_2N.CH_2.CH_2.NH.CH_2.CH_2.NH_2$

↓ Et.O$_2$C.Cl (Ethylchloroformate)

$HN(CO_2.Et).CH_2.CH_2.N(CO_2.Et).CH_2.CH_2.NH(CO_2.Et)$

↓ 98% $HNO_3$

$O_2N.N(CO_2.Et).CH_2.CH_2.N(CO_2.Et).CH_2.CH_2.N(CO_2.Et).NO_2$

↓ Hydrolysis with 20% NaOH followed by acidification with $HNO_3$

$O_2N.NH.CH_2.CH_2.NH.CH_2.CH_2.NH.NO_2$ (Ref 2,pp 3 & 14)

It is a mild expl; when heated in a test tube it melts and decomp with a sudden puff and evoln of fumes; when dropped on a red-hot plate it ignites immediately and burns with a yel flame(Ref 2,pp 26-7). Its UV absorption spectra are described in Ref 3

*Bis(β-nitraminoethyl)-amine Nitrate[called Di(β-nitraminoethyl)-ammonium Nitrate* by Johnson], $O_2N.HN.CH_2.CH_2.NH_2^+(NO_3^-).CH_2.CH_2.NH.NO_2$; mw 292.24, N 28.76%; crysts, mp 152.5-153.5°. Can be prepd as follows:

$O_2N.N(CO_2.Et).CH_2.CH_2.N(CO_2.Et).CH_2.CH_2.N(CO_2.Et).NO_2$

↓ Ammonolysis ($NH_3$ + heat)

$O_2N.HN.CH_2.CH_2.N(CO_2.Et).CH_2.CH_2.NH.NO_2$

↓ Hydrolysis with aq NaOH followed by acidification with $HNO_3$

$O_2N.HN.CH_2.CH_2.NH_2^+(NO_3^-).CH_2.CH_2.NH.NO_2$ (Ref 2,p 13)

On treating this compd with 98% $HNO_3$ there was obtained the explosive:

**Bis(β-nitroxyethyl)-amine Nitrate or Di(β-ethanolamine)-trinitrate,**

$O_2NO.CH_2.CH_2.NH_2^+(NO_3^-).CH_2.CH_2.ONO_2$; mw 258.16, N 21.71%, OB to $CO_2$ -24.8%; crysts(from abs alc), mp 116-17°(Ref 2,p 13), mp 111.7-113.2° (Ref 4); mp 120.5°(Ref 1a). When heated in a test tube, it melts and decomp with a sudden puff & evoln of fumes; when dropped on a red-hot plate, it expl with a flash(Ref 2,pp 26-7). This compd can also be prepd by nitrating diethanolamine as described in Refs 1a and 4. It was patented in Germany(Ref 1a) for use as an expl alone or as a component of expl compositions

(See also Diethanolamine and Derivatives)

*Bis(β-nitraminoethyl)-nitramine or 1,4,7-Trinitro-1,4,7-triazaheptane,*

$O_2N.HN.CH_2.CH_2.N(NO_2).CH_2.CH_2.NH.NO_2$. Attempts of Johnson et al to prep this compd were unsuccessful(Ref 2)

*Refs*: 1)Beil **4**,255 & [695] 1a)Dynamit AG, GerP 500407(1929) & CA **24**,4397(1930) 2)J.R. Johnson,OSRD **915**(1942), 1-3, 12-14 & 26-7 3)R.N.Jones & J.D.Thorn,CanJRes **27B**,831(1949) & CA **44**,2848(1950) 4)J.Cason,Jr,USP 2686804 (1954) & CA **49**,2075(1955)

**Bis(aminoethylamino)-ethane and Derivatives**

*1,2-Bis(2'-aminoethylamino)-ethane; N,N'-Bis(β-aminoethyl)-ethylenediamine; N,N'-Di(β-aminoethyl)-ethylenediamine; 1,4,7,10-Tetrazadecane; Triethylenetetramine or TETA,*

$H_2N.CH_2.CH_2.NH.CH_2.CH_2.NH.CH_2.CH_2.NH_2$; mw 146.24, N 38.32%; liq freezing at -18° and remelting at +12°; bp 157° at 20mm or 174° at 31mm; d 0.9817 at 15°. Can be prepd by interaction of 1,2-dibromoethane with a large excess of ethane-1,2-diamine hydrate(Ref 4) or by other methods(Refs 1,2 & 3)

Its *Tetrapicrate*, $C_6H_{18}N_4.4C_6H_3N_3O_7$, yel crysts, melts with decomp ca 240° (Ref 3,p 1354)

*Refs*: 1)Beil **4**,255 & [695] 2)A.W.Hofmann,Ber **23**,3712(1890) 3)R.G.Fargher,JCS **117**,1353-4 (1920) 4)J.van Alphen,Rec **55**,413-14(1936) & CA **30**,5992-3(1936)

**1,2-Bis(2'-aminoethyl-nitramino)-ethane;** *1,2-Bis(2'-aminoethyl)-ethanedinitramine; N,N'-Di(β-aminoethyl)-ethylenedinitramine or 1,7-Dinitro-1,4,7,10-tetrazadecane,*

$H_2N.CH_2.CH_2(O_2N).N.CH_2.CH_2.N(NO_2).CH_2.CH_2.NH_2$; mw 236.24, N 35.58%; pale yel crysts(from w), mp 242-242.5°(dec); expl when heated in a capillary; ignites when thrown on a red-hot plate; was prepd by adding to an aq soln of N,N'-bis(β-nitraminoethyl)-ethylenediamine dihydrochloride the calcd quantity of std alkali required to form free amine(Ref 2,pp 21-2)

Its *dinitrate*, $C_6H_{16}N_6O_4.2HNO_3$, crysts, mp 210-11°; expl on heating in a test tube and occasionally ignites when dropped on a red-hot plate. Was prepd by boiling the above amine with aq nitric acid, followed by cooling(Ref 2,p 22)

Blomquist et al(Refs 3 & 5) prepd similar compds and on the strength of their work, the structure may be written as:

$O_2N.HN.CH_2.CH_2.\underset{NO_3^-}{NH_2^+}.CH_2.CH_2.\underset{NO_3^-}{NH_2^+}.CH_2.CH_2.NH.NO_2$

Jones & Thorn(Ref 4) detd UV absorption spectra for the compd called by them *1,10-Dinitro-1,4,7,10-tetrazadecane-4,7-dinitrate*, which is evidently identical with the dinitrate described in Ref 2

*Refs:* 1) Beil- not found 2)J.R.Johnson,OSRD Rept **915**(1942),21-2 & 26 3)A.T.Blomquist et al, OSRD Rept **4134**(PBL **18867**)(1944) 4)R.N.Jones & G.D.Thorn, CanJRes **27B**,831(1949) & CA **44**, 2848(1950) 5)A.T.Blomquist & F.T.Fiedorek, USP 2485855 (1949) & CA **44**,3516-17(1950)

**1,2-Bis(2'-nitraminoethyl-nitramino)-ethane;** *1,2-Bis(2'-nitraminoethyl)-ethanedinitramine; N,N'-Di(β-nitraminoethyl-nitramino)-ethane; 1,4,7,10-Tetranitro-1,4,7,10-tetrazadecane or Triethylenetetranitramine,*

$O_2N.HN.CH_2.CH_2.N(NO_2).CH_2.CH_2.N(NO_2).CH_2.CH_2.NH.NO_2$; mw 326.24, N 34.38%; crysts(from hot nitromethane), mp 174.1°; was prepd by chlorination of triethylenetetramine followed by nitration of the resulting product with nitric acid in acetic anhydride(Ref 2). Its expl props were not investigated

*Refs*: 1)Beil- not found 2)G.N.R.Smart & G.R. Wright,JACS **70**,3142(1948) & CA **43**,569-70

**Bis(aminoethyl)-ethanediurethane and Derivatives**

*1,2-Bis(aminoethyl)-ethanediurethane or 4,7-Dicarbethoxy-1,4,7,10-tetrazadecane,*

$C_{12}H_{26}N_4O_4$-not found in Beil or in CA thru 1956

**1,2-Bis(2'-nitraminoethyl)-ethanediurethane;** *N,N'-Di(β-nitraminoethyl)-ethylenediurethane or 4,7-Dicarbethoxy-1,10-dinitro-1,4,7,10-tetrazadecane,*

$O_2N.HN.CH_2.CH_2.\underset{CO_2.C_2H_5}{N}.CH_2CH_2—\underset{CO_2.C_2H_5}{N}.CH_2.CH_2.NH.NO_2$;

mw 380.36, N 22.10%; wh crysts(from methanol), mp 92-4°(dec); ignites and burns with yel flame when dropped on a red-hot plate. Can be prepd from bis(aminoethylamino)-ethane through a series of reactions indicated in Ref 2,pp 15-18 or by treating N,N'-bis(β-nitraminoethyl)-ethylenediamine dissolved in aq NaOH with ethylchloroformate, $Cl.CO_2.C_2H_5$(Ref 2,p 25). Its behavior toward heat is given in Ref 2,p 26 and its UV absorption spectra in Ref 3

Treatment of the above compd with 98% nitric acid as indicated in Ref 2,p 19, resulted in formation of:

**1,2-Bis(2'-nitroxyethyl)-ethanediurethane;** *3,6-Dicarbethoxy-1,8-dinitroxy-3,6-diazaoctane or sym-Di(β-ethanol)-ethylenediurethane Dinitrate,*

$O_2NO.CH_2.CH_2.N(CO_2.C_2H_5)-CH_2.CH_2.N(CO_2.C_2H_5).CH_2.CH_2.ONO_2$;

mw 382.33, N 14.66%; crysts, mp 192-192.5°(dec) ignites and burns rapidly with a yel flame when dropped on a red-hot plate(Ref 2,p 26)

*Refs*: 1)Beil- not found 2)J.R.Johnson,OSRD **915**(1942),15-19 3)R.N.Jones & G.D.Thorn,CanJRes **27B**,832 & 834(1949)

**Bis(aminoethylamino)-propane and Derivatives**

*1,3-Bis(2'-aminoethylamino)-propane; N,N'-Bis(β-aminoethyl)-propanediamine or N,N'-Di(β-aminoethyl)-propanediamine,*

$H_2N.CH_2.CH_2.HN.CH_2.CH_2.CH_2.NH.CH_2.CH_2.NH_2$; col liq, bp 286-7° at atm press; was prepd from 1,3-dibromopropane and 1,2-diaminoethane in abs alc; with acids it forms salts, such as *Picrate*, yel crysts, mp 223° (indefinite)(Ref 2)

**1,3-Bis[(2'-nitraminoethyl)-nitramino]-propane;** *N,N'-Bis(β-nitraminoethyl)-propanedinitramine or N,N'-Di-(nitraminoethyl)-propanedinitramine,*

$O_2N.HN.CH_2.CH_2.(O_2N)N.CH_2.CH_2.CH_2.N(NO_2)-CH_2.CH_2.NH.NO_2$; mw 340.26, N 32.94%. This compd, undoubtedly an expl, was probably prepd by someone on nitration of bis(aminoethylamino)-propane, but it is not described in the open literature

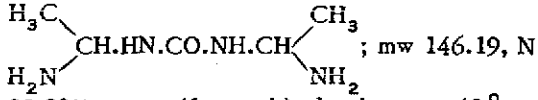
*Refs*: 1)Beil- not found 2)J.van Alphen,Rec **55**, 835(1935) 3)Blatt,OSRD **2014**(1944)- not found

**N,N'-Bis(β-aminoethyl)-ethylenediamine.** See Bis(aminoethylamino)-ethane

**N,N'-Bis(β-aminoethyl)-propanediamine.** See Bis-(aminoethylamino)-propane

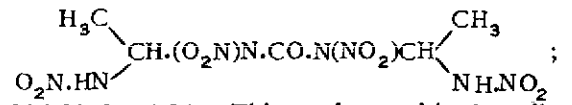
**Bis(aminoethyl)-urea and Derivatives**

*N,N'(or 1,3-Bis[β(or 1)-aminoethyl]-urea or sym-Di(aminoethyl)-urea* (called sym-Di [amino-äthyl]-harnstoff in Ger),



; mw 146.19, N 38.33%, crysts(from eth), dec by w at 40°; was prepd by interaction of acetaldehyde, ammonia and and urea(Ref 2)

**N,N'-Bis(β-nitraminoethyl)-N,N'-dinitrourea,**



;

mw 326.20, N 34.35%. This expl compd is described in conf Aerojet General Corp Rept No 131,Azusa, Calif

*Refs*: 1)Beil- not found 2)A.M.Paquin,Angew-Chem **60A**,269(1948) & CA **43**,1782(1949)

**Bis(aminoguanidine)-1,6-dinitro-2-(aminoguanyl)-biguanidine.** See Vol 1,p A214-R to A215-L

**Bis(aminoguanidinium)-1,6-dinitrobiguanidine.** See Vol 1,p 214-R

**Bis(aminoguanyl)-tetrazene.** Same as Di(aminoguanyl)-tetrazene. See 1-Aminoguanyl-4-aminoguanyl-tetrazene under Guanylaminoguanyl-tetrazene

**Bis(aminomethyl)-propanediamine and Derivatives**

*2,2-Bis(aminomethyl)-1,3-propanediamine; Tetrakis(aminomethyl)-methane; Tetraaminotetramethylmethane or Pentaerythrityltetramine,* $C(CH_2.NH_2)_4$; mw 162.19, N 34.55%. Its monohydrate is a yel viscous liq boiling at 278-82°; can be prepd by heating for 8 hrs at 160° tetrakis(bromomethyl)-methane with concd ammonia in alc, in a closed tube(Ref 2). Its *Picrate* is a yel pdr, decompg at 206-8°

**2,2-Bis(nitraminomethyl)-1,3-propanedinitramine or Pentaerythrityltetranitramine,** $C(CH_2.NH.NO_2)_4$; mw 312.21, N 42.29%, OB to $CO_2$ -41.0%. This is evidently a powerful expl. Some of its props are listed in Ref 3, which is conf. Its description is not found in the open literature

*Refs*: 1)Beil- not found 2)J.van Alphen,Rec **57**, 267(1938) & CA **32**,4546(1938) 3)ADL,PureExpl-Compds,Pt 4(1954),586(C)

**Bis(anilino)-anthraquinone and Derivatives**

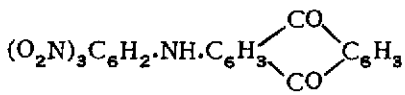
*Bis(anilino)-anthraquinone or Dianilino-anthraquinone,* $C_{26}H_{18}N_2O_2$. Four isomers are described in Beil **14**,199,205,(462,468) & [99,112,117]

*Bis(mononitroanilino)-anthraquinone,* $C_{26}H_{16}N_4O_6$.

One isomer is described in Beil **14**,199

*Bis(dinitroanilino)-anthraquinone,* $C_{26}H_{14}N_6O_{10}$- not found in Beil

**1,5-Bis(2,4,6-trinitroanilino)-anthraquinone;** *1,5-Bis(picrylamino)-anthraquinone or 1,5-Dipicryl-diaminoanthraquinone*[called 1.5-Bis(2.4.6-trinitro-anilino)-anthrachinon or 1.5-Bis-pikrylamino-anthrachinon in Ger],



$(O_2N)_3C_6H_2.NH.C_6H_3$ CO CO $C_6H_3.NH.C_6H_2(NO_2)_3$;

mw 660.42, N 16.97%; orn-red ndls(from nitrobenz); mp dec above 340°; forms a brn vat in alkaline hyposulfite, which produces dk-grn shades on cotton; was prepd from 1,5-diaminoanthraquinone and picryl chloride in boiling nitrobenzene

*Refs*: 1)Beil **14**,(468) 2)C.Seer & R.Weitzenböck, Monatsh **31**,376(1910) & JCS **98** I,571(1910)

**Bis(anilino)-azobenzene and Derivatives**

*Bis(anilino)-azobenzene,*$[C_6H_5.NH.C_6H_4.N:]_2$; mw 364.43, N 15.38%. This compd, although not found in the literature, may be considered as the parent compd of its dinitro deriv described below

*Refs*: 1)Beil- not found 2)CA- not found

**3,3'-Bis(2,4-dinitroanilino)-azobenzene**[called (2.4-Dinitro-diphenylamin)-<3 azo-3>- (2'.4'-dinitro-diphenylamin) in Ger], $[(O_2N)_2C_6H_3$-$NH.C_6H_4.N:]_2$; mw 544.43, N 20.58%; golden-yel ndls(from pyridine), mp 285°; sol in hot pyridine and in benzoic acid ethylester; insol in other solvs; was prepd by the condensation of 3-amino-3'-(2,4-dinitroanilino)-azobenzene with 4-chloro-1,3-dinitrobenzene

*Refs*: 1)Beil **16**,306 2)K.Brand,Ber**40**,3338 (1907) & JCS **92** I, 801(1907)

**Bis(anilino)-ethane and Derivatives**

*1,2-Bis(N-anilino)-ethane; Bis(N-methylamino-benzene; α,β-Dianilino-ethane; 1,2-Bis(phenyl-amino)-ethane or N,N'-Diphenyl-ethylenediamine,* $C_6H_5.NH.CH_2.CH_2.NH.C_6H_5$; lfts(from alc), mp 64.5°; easily sol in alc & eth; was first prepd in 1859 by Hofmann and since then by many others; Bennett(Ref 2) prepd it by heating ethylene-chloride with aniline, while Schouten(Ref 3) used 1,2-dibromoethane and aniline

When nitrated, it yields various-stage nitro compds, up to the *Bitetryl* (called by Brit Ditetryl) which is a HE

*Refs*: 1)Beil **12**,543,(282) & [287] 2)G.M.Bennett, JCS **115**,577(1919) 3)A.E.Schouten, Rec **56**, 541-7(1937) & CA **31**,5335(1937)

*1,2-Bis(2'-nitroanilino)-ethane,* $O_2N.C_6H_4.NH.CH_2.CH_2.NH.C_6H_4.NO_2$; orn-red solid, mp 190-2(Ref 1,p 696 & Ref 3,p 543)

*1,2-Bis(3-nitroanilino)-ethane,* yel-red crysts, mp 206-8°(Ref 1,p 710)

*1,2-Bis(4-nitroanilino)-ethane,* yel-brn solid, mp 216°(Ref 1,p 726 & Ref 3,p 544)

*1,2-Bis(2',4'-dinitroanilino)-ethane,* $(O_2N)_2C_6H_3$-$NH.CH_2.CH_2.NH.C_6H_3(NO_2)_2$; mw 392.28, N 21.43%; yel crysts, mp 313°; can be prepd from 2,4-dinitrochlorobenzene & 1,2-diamino-ethane (Ref 1,p 757 & Ref 3,p 545)

**1,2-Bis(2',4',6'-trinitroanilino)-ethane;** *N,N'-Di-picryl-ethylenediamine or N,N'-Bis(2,4,6-trinitro-phenyl-amino)-ethane,*

$(O_2N)_3C_6H_2.NH.CH_2.CH_2.NH.C_6H_2(NO_2)_3$; mw 482.28, N 23.24%; crysts, mp 230°; dec at higher temp; burned w/o expln when heated on a Pt foil in a flame; sol in hot benz; insol in alc or eth; can be prepd by heating equimol quantities of picrylchloride and 1,2-diaminoethane in alc

*Refs*: 1)Beil **12**,696,710,726,757,770 & [412] 2)K.Jedlicka,JPraktChem **48**,204(1893) 3)A.Schouten,Rec **56**,343-5(1937)

**1,2-Bis(2',4',6'-trinitronitranilino)-ethane;** *N,N'-Dipicryl-ethylenedinitramine; N,N'-Bis(2,4,6-trinitrophenyl-nitramino)-ethane; N,N'-Bis(2,4,6-trinitrophenyl)-ethylene-dinitramine; 2,4,6-Trinitro-1,3,5-tris(methylnitramino)-benzene; 2,4,6,-2',4',6'-(Hexanitrodiphenyl)-ethylene-dinitramine;* **Bitetryl or Ditetryl;** Its British name is **Octyl** [also called *N,N'-Dinitro-N,N'-bis(2,4,6-trinitro-phenyl)-ethylenediamine; Octanitroethylenedi-phenylamine* and *Bis-N(2',4',6'-trinitrophenyl)-1,2-dinitraminoethane*],

$(O_2N)_3C_6H_2.N(NO_2).CH_2.CH_2.N(NO_2).C_6H_2(NO_2)_3$; mw 572.28, N 24.48%, OB to $CO_2$ -44.7%; lt yel fine crysts(from acet or nitrobenz), mp 218-22° (dec) for the pure and 206-7° for tech subst; sol in nitrobenz; sl sol in acet or et acet; insol in w, alc, eth, benz, etc. Several methods for its prepn exist but most of them give impure products. For prepn of the pure compd, Schouten(Ref 3,p 546) recommends nitration of 1,2-bis(2',4'-dinitro-anilino)-ethane or 1,2-bis(2',4',6'-trinitroanilino)-ethane with abs nitric acid. More economical seems to be the method mentioned in Blatt(Ref 10, under N,N'-Dipicrylethylenedinitramine), which involves condensation of ethylenediamine with picryl chloride(yield 89%), followed by nitration of the resulting product with 99% nitric acid at 25°(90% yield)

*Explosive and other properties of Bitetryl: Explosion Temperature-* decompn and no expln up to 360°, but expl when heated rapidly in a flame;

*Heat of Combustion* $Q_c^v$ 1622.6kcal/mol; *Hygroscopicity* at 25° & 100% RH- gains 0.04%; *Impact Sensitivity*- FI 36% PA; comparable to PETN; *Power*, by Ballistic Mortar 123%TNT; *Power* by Trauzl Test 114%PA and 130%TNT; *Thermal Stability at 135°*- not acid and no expln in 300 min(Refs 5,7,8,9 & 10)
*Uses*: Was proposed by Cox(Ref 5) for use as a base chge in blasting caps

*Bitetryl* prepd in France after WWII at the Poudrerie de Sorgues(mp 214°) and examined (after purification) by Médard et al at the Laboratoire Central des Poudres, had the following props(Ref 11): mp 114°(dec) for tech and 226.5°(dec) for purified material; d(max compressed) 1.70; CUP(Fr Trauzl Test) 115%PA; sensibilité à l'amorce(sensitivity to initiation)- 50g cartridge of d 1.10 to 1.70 required 0.30g MF to assure complete detonation; sensibilité au choc (sensitivity to impact)- comparable to Tetryl; vitesse de détonation(velocity of detonation), detd by the Dautriche method- 5600m/s at d 1.0, 6450 at d 1.40, 7350 at d 1.60 and 7250 at d 1.70 (for tech sample, mp 114°)

Médard also examined several binary and ternary mixts contg Bitetryl, such as: a)50-50-Bitetryl/TNT- a cast HE, d 1.48-1.50, vel of deton 7100 to 7400m/s b)50/30/20-Bitetryl/Ethyltetryl-/Tetryl, a castable, plastic HE, d 1.58; it could not be initiated by as much as 2g of MF, but required a compound detonator for complete initiation

*Refs*: 1)Beil **12**,(371) & [426] 2)G.M.Bennett, JCS **115**,576(1919) 3)A.E.Schouten, Rec **56**, 541-7 & 871(1937) 4)G.Desseigne,MP **28**,156 (1938) 5)R.F.Cox,USP 2125221(1938) & CA **32**, 7728(1938) 6)R.C.Elderfield,OSRD **158** (1941),8 7)R.McGill,OSRD **830**(1941),26 8)G.B.Kistiakowsky,OSRD **702**(1942) 9)A.H. Blatt & F.C.Whitmore, OSRD **1085**(1942),47 10) A.H.Blatt,OSRD **2014**(1944)- listed in two places: as N,N'-Dipicrylethylenedinitramine and as 2,4,-6,2',4',6'-(Hexanitrodiphenyl)-ethylenedinitramine 11)L.Médard,MP **33**,47 & 52-5(1951); CA **47**, 5685(1953) 12)Sax(1957)- not found

**Bis(anilinophenyl)-urea and Derivatives**

*N,N'-Bis(4-anilinophenyl)-urea*, $[C_6H_5.NH.C_6H_4.NH.]_2CO$; mw 394.46, N 14.20%. This compd, although not found in the literature, may be considered the parent compd of its dinitro deriv described below

*Refs*: 1)Beil- not found{The N,N'-Bis-(2-anilinophenyl)-urea is described in Beil **13**,[17]}
2) CA- not found

**N,N'-Bis(3,5-dinitro-4-anilinophenyl)-urea**[called N.N'-Bis-(3.5-dinitro-4-anilino-phenyl)-harnstoff in Ger], $[C_6H_5.NH.C_6H_2(NO_2)_2.NH.]_2CO$; mw 574.45, N 19.51%; red lfts(from glac AcOH+w), mp 252°(dec); was prepd by heating 3,5-dinitrobenzoylazide with glac AcOH. Its expl props were not investigated

*Refs*: 1)Beil **13**,[60] 2)H.Lindemann & W.Wessel, Ber **58**,1228(1925) & JCS **128** I,1099(1925)

**Bis(anilino)-propane and Derivatives**

*1,3-Bis(anilino)-propane; 1,3-Bis(phenylamino) -propane; α,γ-Dianilino-propane* or *N,N'-Diphenyl -trimethylenediamine*, $C_6H_5.NH.CH_2.CH_2.CH_2.NH.C_6H_5$; mw 226.31, N 12.38%; crysts, mp 40-1°, bp 244-5° at 11mm; sol in many org solvs and nearly insol in w. Was first obtd as the sulfate by Hanssen(Ref 2) and its base was obtd by Scholtz(Ref 3) as an oil (apparently in the impure state) on treating trimethylenebromide with aniline. Veer(Ref 4) prepd it in the pure state by treating aniline with 1,3 -dibromopropane

The following nitro derivs of this compd are known:

*1,3-Bis(2'-nitroanilino)-propane*, $O_2N.C_6H_4.NH.CH_2.CH_2.CH_2.NH.C_6H_4(NO_2)$; mw 316.30, N 17.71%; orn ppt; was prepd in 33.6% yield by heating an alc soln of a mixt of o-chloronitrobenzene and 1,3-diaminopropane in a sealed tube for 8 hrs at 140°. On nitration it gives the expl *Methylene Ditetryl* (see below)(Ref 4,p 1000)

*1,3-Bis(4-nitroanilino)-propane*, yel crysts, mp 196°; was prepd in 19% yield by heating p-nitroaniline and 1,3-dibromobenzene in a paraffin bath at 150° for 5½hrs. It yields the expl *Methylene Ditetryl* when nitrated(Ref 4,p 1001)

*1,3-Bis(2',4'-dinitroanilino)-propane*, $(O_2N)_2$-$C_6H_3.NH.CH_2.CH_2.CH_2.NH.C_6H_3(NO_2)_2$; mw 406.31, N 20.69%; yel crysts; was prepd by heating equimol quantities of 2,4-dinitrochlorobenzene and 1,3-diaminopropane in alc on a water bath for 2 hrs. It yields the expl *Methylene Ditetryl* when nitrated(Ref 4,p 1001)

**1,3-Bis(2',4',6'-trinitroanilino)-propane** or *1,3 -Bis(2',4',6'-trinitrophenylamino)-propane*, $(O_2N)_3C_6H_2.NH.CH_2.CH_2.CH_2.NH.C_6H_2(NO_2)_3$; mw 496.31, N 22.58%, OB to $CO_2$ -77.3%; yel lfts; mp 199°; expl at higher temp; sol in acet or nitrobenz; sparingly sol in alc, petr eth, chlf or $CCl_4$; insol in eth or w; was prepd by interaction of alc soln of equimol quantities of picryl chloride and 1,3-diaminopropane. It yields *Methylene Di-*

*tetryl* when nitrated(Ref 4,p 1001)

**1,3-Bis(2',4',6'-trinitro-N-nitranilino)-propane; Methylene Ditetryl;** or *1,3-Bis(2',4',6'-trinitrophenyl-nitramino)-propane*[called N,N'-(Hexanitrodiphenyl)-propylene-1,3-dinitramine by Blatt], $(O_2N)_3C_6H_2.N(NO_2).CH_2.CH_2.CH_2.N(NO_2),C_6H_2(NO_2)_3$; mw 586.31, N 23.89%, OB to $CO_2$ -51.8%; pale yel crysts(from alc+acet), mp 199-201°; sol in boiling acet; insol in w, alc, eth, petr eth, benz, toluene, chlf or $CCl_4$; the pure product can be obtd by nitrating any of the above nitro compds with abs nitric acid(Ref 4,pp 1000-1); the tech product(mp ca 189°) can be prepd by two-stage nitration of 1,3-bis(anilino)-propane as described in Ref 4,p 997. Its expl props were not detd

*Refs*: 1)Beil **12**,548 2)A.Hanssen,Ber **20**,781 (1887) 3)M.Scholtz,Ber **32**,2251(1899) 4)W.L. Veer,Rec **57**,988,997,1000-2 & 1013(1938) 5)Blatt,OSRD **2014**(1944)

**Bis(5-aryl-2'-tetrazolyl)-formimine,**

Ar.C(=N-N=C(-N=N-NH)-N=C.Ar; class of compds;

was discussed by R.L.Scott et al in JACS **75**, 5309-12(1953). Nitrated derivs of these compds might find use in expl compns or in proplnts

**Bis(azidobenzylidene)-azine and Derivatives**

**Bis-(α-azidobenzylidene)-azine**[called Bis-[α-azido-benzyliden]-hydrazin or Dibenzhydrazidazid in Ger], $C_6H_5.C(N_3):N.N:C(N_3).C_6H_5$, mw 290.28, N 38.60%, ndls(from $CCl_4$) having an odor of benzonitrile; mp 139°(dec); expl on heating over a flame; sol in chlf, $CCl_4$, ligroin or hot benz; diffc sol in methanol or alc but more sol in warm eth; insol in w. It can be obtained in addn to other products by the reaction of bis-(α-chlorobenzylidine)-azine with 2 moles of $NaN_3$ in boiling methanol and in a $CO_2$ atm. Other props are given in Refs 1 & 2

*Refs*: 1)Beil **9**, [219] 2)R.Stollé & A.Netz,Ber **55**,1301(1922)

**Bis(α-azido-nitro-benzylidene)-azine,** $O_2N.C_6H_4.C(N_3):N.N:C(N_3).C_6H_4.NO_2$, mw 380.29, N 36.83%. Two isomers are known: *Bis(α-azido-3-nitro-benzylidene)-azine*(called Di-m-nitrobenzhydrazidazid in Ger), fine yel crysts, explg mildly ca 156°; fairly sol in chlf; difficultly sol in eth or alc. Was prepd by treating an alc soln of bis(α-chloro-3-nitro-benzylidene) -azine with Na azide(Ref 2,pp 327 & 337-8) and *Bis(α-azido-4-nitro-benzylidene)-azine*(called Di-p-nitrobenzhydrazidazid in Ger), red-yel crysts explg mildly ca 161°. Was prepd by treating an alc soln of bis(α-chloro-4-nitro-benzylidene)-azine with Na azide. As a by-product of this reaction, there was obtained a small quantity of a product which exploded violently ca 149°. Its structure was not established(Ref 2,pp 327 & 335-6)

*Refs*: 1)Beil-not found 2)R.Stollé et al,JPrakt-Chem **137**,327 & 335-8(1933) & CA **27**,4233(1933)

**Bis(α-azidobenzylidene)-hydrazine**(called Dibenzhydrazidazid in Ger), $C_6H_5.C(N_3):N.N:C(N_3).C_6H_5$; mw 290.28, N 38.60%; long, fine ndls(from $CCl_4$), mp 139°(dec), expl when heated in an open flame; readily sol in chlf, $CCl_4$, ligroin or hot benz; mod sol in warm eth; diffc sol in MeOH or alc; insol in w; was prepd by treating bis-(α-chlorobenzylidene)-hydrazine with 2 mols of Na azide in MeOH and boiling for 16hrs in a $CO_2$ atm

*Refs*: 1)Beil **9**,[219] 2)R.Stollé & A.Netz,Ber **55**,1301(1922) & CA **16**,3899(1922)

**3,4-Bis[(azidoformyl)methyl]-hexanedioyl Azide,** $C_{10}H_{10}N_{12}O_4$. A name given in CA 5th Decennial Formula Index, p 555F for the compd called by us as *β,β'-Bis(carboxymethyl)-adipic Acid Tetraazide or Ethane-1,1,2,2-tetraacetic Acid Tetraazide*. See under Ethane-1,1,2,2-tetraacetic Acid

**Bis[α-azido-3(or 4)-nitrobenzylidene]-azine.** See under Benzaldehydeazine

**Bis-(azidothioformyl)-disulfide**(called *Azidocarbondisulfide* by Audrieth and Bis-azidothioformyl-disulfid or Azidoschwefelkohlenstoff in Ger), $N_3.C(:S).S.S.C(:S).N_3$, mw 236.31, N 35.57%; wh solid; mp-detonates with great violence >40° or when subjected to shock; unstable even at RT; v sl sol in w(0.03%); sl sol in benz or $CS_2$; sol in methanol, ethanol, ether, $CCl_4$ & xylene; v sol in acet & et acet. Can be prepd by treating azidodithiocarbonic acid(see Vol 1,p A632-L) or its alkaline salts with an oxidizing agent, such as iodine in KI soln, $H_2O_2$, $KMnO_4$ etc. Only very small quantities(not more than 1g) must be prepd at a time and stored for not longer than 48hrs in a desiccator over $P_2O_5$. Explns often occur during its prepn and handling. It is a more violent expl than azidodithiocarbonic acid(Refs 1,2 & 3)

A violent expln takes place when bis-(azidothioformyl)-disulfide is treated with bromine or ammonia(Ref 1)

*Refs*: 1)Beil **3**,[160] & {357} 2)L.F.Audrieth, ChemRevs **15**,197(1934) 3)InorgSynth **1**(1939), 82-4

**Bis(benzalaminoguanidine)-1,6-dinitrobiguanidine.** See Vol 1,p A215-L

**Bis(benzeneazo)-azobenzene and Derivatives**

*Bis(benzeneazo)-azobenzene or Bis(phenylazo)-azobenzene*[called 4,4'-Bis-benzolazo-azobenzol or Bis-(4-benzolazo-phenyl)-diimid in Ger], $[C_6H_5.N:N.C_6H_4.N:]_2$; mw 390.43, N 21.53%; red flakes(from benz or toluene), mp 229°; on rapid heating becomes a dk-red liq at ca 235°; other props and prepn are given in Beil **16**,86,(232) & [30]

*4,4'-Bis(4-nitrobenzeneazo)-azobenzene or 4,4'-Bis(4-nitrophenylazo)-azobenzene,* $[O_2N.C_6H_4.N:N.C_6H_4.N:]_2$; mw 480.43, N 23.33%, orn-brn ndls(from solv naphtha) or garnet-red lfts (from xylol or MNB), mp 285-294°; diffc sol in most org solvs; was prepd by heating 4-nitroso-4'-nitrohydrazobenzene with dil NaOH at 100° or with solv naphtha; and from 4,4'- dinitrohydrazobenzene by heating with dil NaOH at 100° or with alc in a sealed tube in atm of N at 170°. Other props are given in the Refs

*Refs*: 1)Beil **16**,(232) 2)K.Ueno & S.Akiyoshi, JACS **76**,3668(1954) & CA **49**,10906(1955)

*Note: Bis-dinitro.* $C_{24}H_{14}N_{10}O_8$ or *Bis-trinitrophenylazo,* $C_{24}H_{12}N_{12}O_{12}$, *Derivatives* were not found in Beil or in CA thru 1956

**Bis(benzeneazo)-azoxybenzene and Derivatives**

*4,4'-Bis(benzeneazo)-azoxybenzene or 4,4'-Bis-(phenylazo)-azoxybenzene* (called 4.4'-Bis-benzolazo-azoxybenzol in Ger),$[C_6H_5.N:N.C_6H_4.]_2(N_2O)$; mw 406.43, N 20.68%; orn-yel ndls(from glac AcOH) and yel crysts or red lfts(from benz), mp 215-218°; other props and methods of prepn are given in Beil **16**,658,(394) & [341]

*4,4'-Bis(2-nitrobenzeneazo)-azoxybenzene or 4,4'-Bis(2-nitrophenylazo)-azoxybenzene,* $[O_2N.C_6H_4.N:N.C_6H_4.]_2(N_2O)$; mw 496.43, N 22.57%; dk-yel ndls, mp darkens and dec ca 258° without melting; insol in common org solvs; other props and methods of prepn are given in Beil **16**, 658

*4,4'-Bis-(2,6-dinitrobenzeneazo)-azoxybenzene or 4,4'-Bis(2,6-dinitrophenylazo)-azoxybenzene* $[(O_2N)_2.C_6H_3.N:N.C_6H_4.]_2(N_2O)$; mw 586.43, N 23.89%; orn-yel ndls, mp 255.6°; diffc sol in common org solvs; was prepd from benzoquinone-1,4-oxime-2,6-dinitrophenylhydrazone by treatment with dil NaOH. Its expl props were not investigated

*Refs*: 1)Beil **16**,(394) 2)W.Borsche & D.Rantscheff,Ann **379**,174(1911) & JCS **100** I, 331(1911)

**4,4'-Bis(2,4,6-trinitrobenzeneazo)-azoxybenzene** or *4,4'-Bis(2,4,6-trinitrophenylazo)-azoxybenzene,* $[(O_2N)_3C_6H_2.N:N.C_6H_4.]_2(N_2O)$; mw 676.44, N 24.85%; dull brn ndls, mp expl ca 321° with a flash; was prepd by reacting 2,4,6-trinitro-phenylhydrazine with p-benzoquinoneoxime in aq alc HCl, followed by boiling with glac AcOH to effect conversion

*Refs*: 1)Beil **16**, [341] 2)W.Borsche,Ber **54**,1290 (1921) & JCS **120** I, 625(1921)

**Bis(benzeneazoxy)-azoxybenzene and Derivatives**

*Bis(benzeneazoxy)-azoxybenzene; Bis(phenylazoxy)-azoxybenzene* (called 4.4'-Bis-benzolazoxy-azoxybenzol in Ger), $[C_6H_5(N_2O).C_6H_4.]_2(N_2O)$; mw 438.43, N 19.17%. The *4,4'-Bis* deriv exists in two forms: *higher melting form,* golden-yel crysts (from benz or petr eth), mp ca 230°, becomes a thick, viscous liq dec at 265°; and *lower melting form,* copper-red flakes(from benz), mp 223°. Other props and methods of prepn are given in Beil **16**,(381) & [324]

*Note: Bis(mononitrophenylazoxy)-*, $C_{24}H_{16}N_8O_7$; *Bis(dinitrophenylazoxy)-*, $C_{24}H_{14}N_{10}O_{11}$; and *Bis(trinitrophenylazoxy)-azoxybenzene,* $C_{24}H_{12}N_{12}O_{15}$, *Derivatives* were not found in Beil or in CA thru 1956

**4,5-Bis(benzoyl)-1,2,3,6-dioxadiazine.** Same as 4,5-Dibenzoyl-1,2,3,6-dioxadiazine

**Bis(benzoyl)-hydrazine and Derivatives**

*Bis(benzoyl)-hydrazine or 1,2-Dibenzoyl-hydrazine* (called N.N'-Dibenzoyl-hydrazin in Ger), $C_6H_5.CO.NH.NH.CO.C_6H_5$; mw 240.25, N 11.66%; compd is dimorphic, existing in two cryst forms: very fine ndls(from boiling alc or AcOH) and monoclinic prisms, both forms have mp 237-241°. This compd forms numerous cryst salts; its prepn and other props are given in Beil **9**,324,(131) & [216]

**N,N'-Bis(nitrobenzoyl)-hydrazine**[called N.N'-Bis(nitro-benzoyl-hydrazin in Ger], $[O_2N.C_6H_4.CO.NH-]_2$; mw 330.25, N 16.97%; three derivs of this compd exist: *Bis(2-nitrobenzoyl)-hydrazine,* ndls(from NB) or pltlts(from AcOH), mp expl mildly on heating in a flame(Ref 1); *Bis(3-nitrobenzoyl)-hydrazine*, lfts or ndls (from alc or AcOH), mp 242°(Ref 2); and *Bis-(4-nitrobenzoyl)-hydrazine*, yel ndls, mp 291° (Ref 3). Other props and methods of prepn of these isomers are given in the Refs

*Refs*: 1)Beil **9**,375 & [247] 2)Beil **9**,388 3)Beil **9**,400 & [274]

**N,N'-Bis(3,5-dinitrobenzoyl)-hydrazine** [called N.N'-Bis-(3.5-dinitrobenzoyl)-hydrazin in Ger], $[(O_2N)_2C_6H_3.CO.NH-]_2$; mw 420.25, N 20.00%; yel pdr, mp 276°; sol in alkalies and in concd $H_2SO_4$; diffc sol in alc or AcOH; insol in w or acids; was prepd by the action of iodine on 3,5 -dinitrobenzoylhydrazide in boiling alc soln. Other props and methods of prepn are given in the Refs. Its expl props were not detd

*Refs*: 1)Beil **9**,415 2)T.Curtius & A.Riedel, JPraktChem **76**,251(1907) & JCS **92** I, 970(1907)

*Bis(trinitrobenzoyl)-hydrazine*, $[(O_2N)_3C_6H_2.CO.NH-]_2$; not found in Beil or in CA thru 1956

**Bis(benzoyl)-peroxide.** Same as Dibenzoylperoxide

**Bis(benzoylperoxy)-cyclohexane and Derivatives**

**1,1'-Bis(benzoylperoxy)-cyclohexane** or *1,1-Di-(benzoperoxy)-cyclohexane* (called *Peroxybenzoic Acid, Cyclohexylidene Ester* in CA Formula Index for 1950), $C_6H_5.CO.OO\text{-}C_6H_{10}\text{-}OO.CO.C_6H_5$; mw 356.36, O 26.94%; rhmb prisms, mp 96°; expl when heated on a spatula in a flame; was prepd by benzoylation of 1-hydroxyperoxycyclohexyl-1 -hydroxycyclohexyl, $C_{12}H_{22}O_5$ (Compd VII of Ref 2,p 8) in pyridine with $C_6H_5.CO.Cl$ at 0° (Ref 2,p 17)

**1,1-Bis(p-nitrobenzoylperoxy)-cyclohexane or** *1,1-Di(p-nitrobenzoperoxy)-cyclohexane* (called *Peroxybenzoic Acid,p-Nitrocyclohexylidene Ester* in CA Formula Index for 1950), $O_2N.C_6H_4.CO.OO\text{-}C_6H_{10}\text{-}OO.CO.C_6H_4.NO_2$; mw 446.36, O 35.85%, N 6.28%; lt yel ndls(from alc) or rhmb prisms(from AcOH), mp- expl at 120°; was prepd by treating 1-hydroxyperoxycyclohexyl -1-hydroxycyclohexyl in pyridine with p-nitro-benzoyl chloride at 0° (Ref 2,p 17)

*Refs*: 1)Beil- not found 2)R.Criegee et al,Ann **565**,8 & 17(1949); CA **44**,1917-16(1950) 3)Tobolsky & Mesrobian(1954),178

**Bis(benzoylperoxy)-dicyclohexylperoxide and Derivatives**

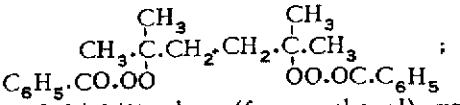
*1,1'-Bis(benzoylperoxy)-dicyclohexylperoxide* [called *Peroxybenzoic Acid Diester with Bis(1 -hydroxycyclohexyl)-peroxide* in CA Formula Index for 1950],
$C_6H_5.CO.OO\text{-}C_6H_{10}.OO.C_6H_{10}\text{-}OO.CO.C_6H_5$; mw 470.50, O 27.21%; prisms(from methanol), mp 92-3°; was prepd by benzoylation of bis(1-hydro-peroxycyclohexyl)-peroxide, $C_{12}H_{22}O_6$, pyridine with $C_6H_5.CO.Cl$ at 0°(Ref 2,pp 8 & 18)

*Refs*: 1)Beil- not found 2)R.Criegee et al,Ann **565**,8 & 18(1949)

*1,1'-Bis(p-nitrobenzoylperoxy)-dicyclohexylperoxide*, $C_{26}H_{28}N_2O_{12}$. This compd, probably expl, is not described in the literature, but it seems that it may be prepd by treating bis(1-hydroperoxy-cyclohexyl)-peroxide in pyridine with p-nitro-benzoyl chloride

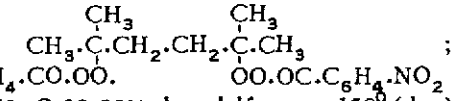
**Bis(benzoylperoxy)-dimethyl-hexane and Derivatives**

**2,5-Bis(benzoylperoxy)-2,5-dimethyl-hexane** (called *Peroxybenzoic Acid, 1,1,4,4-Tetramethyl-tetramethylene Ester* in CA Formula Index for 1949),



mw 386.43, O 24.84%; plates(from methanol), mp 117°; expl in a flame; was prepd by treating 2,5 -bis(hydroperoxy)-2,5-dimethyl-hexane(qv) with benzoyl chloride in abs pyridine(Ref 2,p 141)

**2,5-Bis(p-nitrobenzoylperoxy)-2,5-dimethyl-hexane** (called *Peroxybenzoic Acid,p-Nitrol, 1,4,4-tetra-methyltetramethylene Ester* in CA Formula Index for 1949),



mw 476.43, O 38.58%; lt yel lfts, mp 150° (dec); can be prepd by treating 2,5-bis(hydroperoxy)-2,5 -dimethyl-hexane with p-nitrobenzoyl chloride in abs pyridine. Its expl props were not investigated

*Refs*: 1)Beil- not found 2)R.Criegee & H. Dietrich,Ann **560**,141(1948) & CA **43**,6190(1949)

**Bis(benzoylperoxy)-fluorene and Derivatives**

**9,9'-Bis(benzoylperoxy)-fluorene or** *9,9'-Di(benz-peroxy)-fluorene* (called *Peroxybenzoic Acid,9 -Fluorenylidene Ester* in CA Formula Index for 1950), $C_6H_5.CO.OO$ \ $C_{13}H_8$ / $C_6H_5.CO.OO$; mw 470.41, O 27.21%; col rhmb prisms(from methanol), mp 106°; expl when heated on a spatula; was prepd by benzoyl-ation of the mol aggregate $C_{39}H_{26}O_6$(Compd XVIII of Ref 2,pp 14 & 20), listed here as Bis(9 -hydroperoxy)-fluorene+2 Fluorenones(Adduct), in pyridine with $C_6H_5CO.Cl$ at 0°(Ref 2,pp 14 & 20)

**9,9'-Bis(p-nitrobenzoylperoxy)-fluorene** or *9,9-Di-(p-nitrobenzoperoxy)-fluorene* (called *Peroxybenz-oic Acid,p-Nitrofluorenylidene Ester* in CA For-mula Index for 1950),

$O_2N.C_6H_4.CO.OO$ \
$C_{13}H_8$; mw 528.41, O 30.28%; \
$O_2N.C_6H_4.CO.OO$ /
lt yel crysts, mp 149-50°; expl at higher temp; was prepd by reacting the above mol aggregate, $C_{39}H_{26}O_6$, in pyridine with p-nitrobenzoyl chloride at 0°(Ref 2,p 21)
*Refs*: 1)Beil- not found 2)R.Criegee et al,Ann **565**,14 & 20-1(1949); CA **44**,1917(1950)

**9,9'-Bis(benzoylperoxyfluorenyl)-peroxide** or *9,9'-Di(benzoperoxy)-9,9'-fluorene Peroxide* [Dibenzoate of 9,9'-Di(hydroperoxy)-9,9'-fluorene Peroxide designated in Ref 2,p 15 as "Dibenzoat des Peroxyds XX"] [called *Peroxybenzoic Acid,Diester with Bis(9-hydroxy-9-fluorenyl)-peroxide* in CA Formula Index for 1950],
$C_6H_5.CO.OO.C_{13}H_8.OO.C_{13}H_8.OO.OC.C_6H_5$; mw 634.61, O 20.17%; col crysts(from benz), mp 135°(often with expln); can be prepd by benzoylation of $H.OO.C_{13}H_8.OO.C_{13}H_8.OO.H$ in pyridine with $C_6H_5.CO.Cl$ at 0°
*Refs*: 1)Beil- not found 2)R.Criegee et al,Ann **565**,21(1949) & CA **44**,1917(1950)

**Bis(benzyl)-amine.** Same as Dibenzylamine

**Bis(benzylideneamino)-guanidine and Derivatives**
*Bis(benzylideneamino)-guanidine*(called N.N'-Bis-benzylidenamino-guanidin; ω.ω'-Dibenzyliden-diaminoguanidin; sym-N.N'-Bis-benzalamino-guanidin or Kohlensäure-imid-bis-benzalhydrazid in Ger), $NH.N{:}CH.C_6H_5$ \
$C{:}NH$ ; mw 265.31, N 26.40%; yel \
$NH.N{:}CH.C_6H_5$
nlds(from alc), mp 176°; forms numerous cryst salts; other props and methods of prepn are given in Beil **7**,230,(127) & [173]

**Bis(3-nitrobenzylideneamino)-guanidine**[called N.N'-Bis-(3-nitro-benzalamino)-guanidin or Kohlensäure-imid-bis-(3-nitro-benzalhydrazid) in Ger], $(O_2N.C_6H_4.CH{:}N.NH-)_2C{:}NH$; mw 355.31, N 27.60%; yel crysts, mp 240-242°; insol in common org solvs; was prepd by reacting the hydrobromide of N,N'-diamino-guanidine and m-nitrobenzaldehyde in alc. It forms salts, such as the *Hydrobromide*, $C_{15}H_{13}N_7O_4$+HBr, yel pdr,gradually reddens in the air and dec at 292°. Other props are given in the Refs. The expl props of the compd and its salts were not detd
*Refs*: 1)Beil **7**,(140) 2)A.Gaiter,Gazz **45** I,454 (1915) & JCS **108** I,656(1915)

**Bis(biphenyl)-triazene and Derivatives**
**1,III-Bis(p-biphenyl)-triazene**; *1,3-Di(p-biphenyl)-triazene; 4-Diazoaminobiphenyl* or *4,4'-Diphenyldiazoaminobenzene* [called 1.3-Bis-p-diphenylyl-triazen-(1) in Ger],
$C_6H_5.C_6H_4.N{:}N.NH.C_6H_4.C_6H_5$; mw 349.42, N 12.03%; yel plates or ndls(from warm alc), mp 147°; sol in benz, AcOH, alc & some other org solvs; insol in w & dil acids; can be prepd by diazotizing p-aminobiphenyl, $C_6H_5.C_6H_4.NH_2$ (2 mols) in AcOH with Na nitrite(1 mol) or by other methods(Ref 1)

Some of its salts are expl, for example: *Perchlorate*, $(C_6H_5.C_6H_4)_2N_2.NH.ClO_4$; crysts, expl on heating; was prepd by treating the triazene with perchloric acid and separating the resulting ppt. It was proposed for use in primary and initiating compns(Ref 4)

In addn to the above p-isomer, called by Fishbein(Ref 4) *Diazo-4-aminodiphenyl Perchlorate*, there was prepd the o-isomer, called *Diazo-2-aminodiphenyl Perchlorate*. This isomer also proved to be expl
*Refs*: 1)Beil **16**,[356] 2)D.Vorländer,Ber **58**, 1914(1925) 3)F.Bell et al,JCS **1926**,1246 4)M.S.Fishbein,VoyennayaKhimia **1933**,No 6,3-8 & CA **29**,7077(1935)

**Bis(biphenylyl)-amine and Derivatives**
*Bis(p-biphenylyl)-amine* (called 4.4'-Diphenyl-diphenylamin or Bis-p-diphenylyl-amin in Ger), $[C_6H_5.C_6H_4-]_2NH$; mw 321.40, N 4.36%; lfts (from benz or xylol), mp 209°; other props and methods of prepn are given in Beil **12**,(546) & [755]

**Bis(2,4,6-trinitro-p-biphenylyl)-amine or** *2,4,6,2',4',6'-Hexanitrobiphenylyl-amine* {called Bis 3.2'.-4'-trinitro-diphenylyl-(4)-amin in Ger(Ref 1) and 4,4'-Bis-op-dinitrophenyl-2,2'-dinitrodiphenylamine by LeFèvre et al(Ref 2)},
$(O_2N)_2C_6H_3.C_6H_3(NO_2)$-NH-$C_6H_3(NO_2).C_6H_3$-$(NO_2)_2$, mw 591.40, N 16.58%; lt-yel ndls(from phenol+alc), mp 256-7°; diffc sol in common solvs; was prepd by passing a current of dry ammonia through a soln of 4'-bromo-2,4,3'-trinitrobiphenyl in boiling nitrobenzene. Its expl props were not detd
*Refs*: 1)Beil **12**,[764] 2)J.W.LeFèvre et al,JCS **1927**,2337 & CA **22**,69(1928)

**Bis(bromoanilino)-ethane and Derivatives**
*1,2-Bis(bromoanilino)-ethane* or *1,2-Bis(bromophenylamino)-ethane*,
$Br.C_6H_4.NH.CH_2.CH_2.NH.C_6H_4.Br$. Two isomers are described in Ref 2,pp 550 & 557. They may be considered as parent compds of the nitro

derivs, although not necessarily used for their prepn

*1,2-Bis(bromo-nitroanilino)-ethane* $Br(O_2N)C_6H_3$-$NH.CH_2.CH_2.NH.C_6H_3(NO_2)Br$. Three isomers are described in Ref 2,pp 551,558 & 864

**1,2-Bis(bromo-dinitro-nitranilino)-ethane,** $C_{14}H_8Br_2N_8O_{12}$; mw 640.10, N 17.50%. Two isomers are known: *1,2-Bis-N-(2'-bromo-4',6'-dinitronitranilino)-ethane,* $Br(O_2N)_2C_6H_2.N(NO_2).CH_2.CH_2.N(NO_2).C_6H_2$-$(NO_2)_2Br$, col crysts, mp 240; was prepd by nitrating 1,2-bis(2'-bromoanilino)-ethane with absol $HNO_3$ at 0°(Ref 2,p 551). Its expl props were not detd *1,2-Bis-N-(4'-bromo-2',6'-dinitro-nitranilino)-ethane*, pale-yel ndls, mp 205°; was prepd by nitrating 1,2-bis(4'-bromoanilino)-ethane or 1,2-bis-(4'-bromo-2'-nitroanilino)-ethane with absol $HNO_3$ at 0°(Ref 2,p 557). Its expl props were not detd

**1,2-Bis(bromo-trinitro-nitranilino)-ethane,** $C_{14}H_6Br_2N_{10}O_{16}$; mw 730.10, N 19.18%; One isomer is known: *1,2-Bis-N-(5'-bromo-2',4',6'-trinitro-nitranilino)-ethane* or *1,2-Bis [N-(5-bromo-2',4',6'-trinitrophenyl)-nitramino]-ethane,* $Br(O_2N)_3C_6H.N(NO_2).CH_2.CH_2.N(NO_2).C_6H(NO_2)_3$-Br, crysts, mp 187°; was prepd by nitrating 1,2-bis-N-(5'-bromo-2'-nitroanilino)-ethane with absol nitric acid at 0°(Ref 2,p 863). Its expl props were not detd

*Refs*: 1)Beil- not found 2)A.E.Schouten,Rec **56**, 550ff, 557ff, 863ff(1937) & CA **31**,5335 & 7045(1937)

**Bis(bromoanilino)-propane and Derivatives**

*1,3-Bis(bromoaniline)-propane or 1,3-Bis(bromo-phenylamino)-propane,* $Br.C_6H_4.NH.CH_2.CH_2.CH_2.NH.C_6H_4.Br$. One isomer is described in Ref 2,p 1009

*1,3-Bis(bromo-nitroanilino)-propane,* $Br(O_2N).C_6H_3.NH.CH_2.CH_2.CH_2.NH.C_6H_3(NO_2)$-Br. One isomer is described in Ref 2,p 1009

*1,3-Bis(bromo-dinitroanilino)-propane,* $Br(O_2N)_2.C_6H_2.NH.CH_2.CH_2.CH_2.NH.C_6H_2(NO_2)_2$-Br. One isomer is described in Ref 2,p 1009

*1,3-Bis(bromo-dinitro-nitranilino)-propane,* $C_{15}H_{10}Br_2N_8O_{12}$; mw 654.13, N 17.12%. One isomer is known: *1,3-Bis-N-(4'-bromo-2',6'-dinitro-nitranilino)-propane,* $Br(O_2N)_2C_6H_2.N(NO_2).CH_2.CH_2.CH_2.N(NO_2)$-$C_6H_2(NO_2)_2Br$; cream-col scales(from dil acet); mp 167°, expl at higher temp; was prepd by nitrating 1,3-bis(4'-bromoanilino)-propane or 1,3-bis(4'-bromo-2',6'-dinitro-anilino)-propane with absol $HNO_3$ at 0° (Ref 2,pp 1009-10 & 1014)

**1,3-Bis(bromo-trinitro-nitranilino)-propane,** $C_{15}H_8Br_2N_{10}O_{16}$; mw 744.13, N 18.81%. One isomer is known: *1,3-Bis-N-(5'-bromo-2',4',6'-trinitro-nitranilino)-propane* or *1,3-Bis [N-(5'-bromo-2',4',6'-trinitrophenyl)-nitramino]-propane,* $Br(O_2N)_3C_6H.N(NO_2).CH_2.CH_2.CH_2.N(NO_2)$-$C_6H(NO_2)_3Br$; crysts, mp 117°; sol in acet, benz toluene, glac AcOH & boiling alc; sparingly sol in eth, petr eth, chlf & $CCl_4$. Was prepd by nitrating 1,3-bis(5'-bromo-2'-nitroanilino)-propane with absol $HNO_3$ at 0°. It is a powerful explosive (Ref 2,pp 1011 & 1014)

*Refs*: 1)Beil- not found 2)W.L.C.Veer,Rec **57**, 1009-12 & 1014(1938) & CA **33**,1287(1939)

**1,2-Bis(bromophenylamino)-ethane.** See Bis(bromo-anilino)-ethane

**1,3-Bis-N-(4'-bromophenylamino)-propane.** See Bis(bromoanilino)-propane

**2,2-Bis(t-butylperoxy)-butane,**

$$(CH_3)_3C\text{-}OO\text{-}\underset{\displaystyle CH_3}{\overset{\displaystyle CH_2CH_3}{\overset{|}{\underset{|}{C}}}}\text{-}OO\text{-}C(CH_3)_3$$

mw 234.44, O 27.31%; col mobile liq, mp -0.8°, bp 26° at 0.2 mm and 50° at 2 mm; expl violently at 125-7°; *d* 0.889 at 20°; $Q_c$ 1869 kcal/mol; $n_D$ 1.415 at 20°; miscible with acet, octane or toluene; insol in q; no serious toxicological hazard in normal handling but high concns of vapor or liq in contact with skin should be avoided; can be prepd by reacting t-butyl hydroperoxide with methyl ethyl ketone in the presence of an acid catalyst(Refs 2 & 3)

This liq must not be distilled at atm press; in *a concd state* it can be decompd explosively above 85° and caution should be exercized in this regard. This compd is sensitive to impact and burns rapidly when ignited(Ref 3)

Wiles et al(Ref 4) have found 2,2-bis(t-butylperoxy)butane to be useful as a polymerization sensitizer(or "catalyst"), Diesel fuel ignition accelerator and as a reagent of org syntheses

*Refs*: 1)Beil- not found 2)F.H.Dickey,USP 2400041(1946) & USP 2455569(1948) 3)F.H. Dickey et al,JACS **71**,1432(1949) & IEC **41**,1673 (1949) 4)Q.T.Wiles et al, IEC **41**,1679(1949) 5)Tobolsky & Mesrobian(1954),180

**2,2-Bis(t-butylperoxy)-propane**

$$(CH_3)_3C\text{-}OO\text{-}\underset{\displaystyle CH_3}{\overset{\displaystyle CH_3}{\overset{|}{\underset{|}{C}}}}\text{-}OO\text{-}C(CH_3)_3$$

mw 220.30, O 29.05%; col mobile liq, $n_D$ 1.4098. It was prepd by Dickey et al but not examined as an expl

*Refs*: 1)Beil- not found 2)F.H.Dickey et al,JACS

71, 1433(1949)

**Bis(caproyl)•peroxide.** Same as Dicaproyl Peroxide

**Bis(carboxamide)•acetylene.** See Acetylenedicarboxamide, Vol 1,p A65-L

**Bis(carboxanilide)•acetylene or Di(N•phenyl•carboxamide)•acetylene.**
$C_6H_5.NH.CO.C{:}C.CO.NH.C_6H_5$ and its **Hexa•nitro Derivative,**
$(O_2N)_3C_6H_2.NH.CO.C{:}C.CO.NH.C_6H_2(NO_2)_3$, are described in conf 2nd Rept, ADL, Synthesis HE's(1951),142-3 & 153

**β,β'-Bis(carboxymethyl)•adipic Acid Tetraazide.** Same as Ethane-1,1,2,2,-tetraacetic Acid Tetraazide

**Bis(3•carboxypropionyl)•peroxide.** See Bis(succinyl)-peroxide

**Bis(chloroanilino)•ethane and Derivatives**
*1,2-Bis(chloroanilino)-ethane or 1,2-Bis[N-(chlorophenyl)-amino]-ethane,*
$Cl.C_6H_4.NH.CH_2.CH_2.NH.C_6H_4.Cl$. Two isomers are described in Ref 2,pp 547 & 554
*1,2-Bis(chloro-nitroanilino)-ethane* or *1,2-Bis[N-(chloronitrophenyl)-amino]-ethane,*
$Cl(O_2N).C_6H_3.NH.CH_2.CH_2.C_6H_3(NO_2)Cl$. Three isomers are described in Ref 2,pp 549,555 & 863
**1,2•Bis(chloro•dinitro•nitranilino)•ethane or 1,2•Bis[N•(chloro•dinitrophenyl)•nitramino]•ethane,**
$Cl(O_2N)_2C_6H_2.N(NO_2).CH_2.CH_2.N(NO_2).C_6H_2(NO_2)_2Cl$; mw 551.18, N 20.33%. Two isomers are described in the literature: *1,2-Bis-N-(2'-chloro-4,6'-dinitro-nitranilino)-ethane or 1,2-Bis[N-(2'-chloro-4',6'-dinitrophenyl)-nitramino]-ethane,* fine col crysts, mp 238°; was prepd by nitrating 1,2-bis((2'-chloro-4'-nitroanilino)-ethane 1,2-bis(2'-chloro-4',6'dinitroanilino)-ethane with abs nitric acid at RT (Ref 2,p 549). Its expl props were not detd *1,2-Bis-N-(4'-chloro-2',6'-dinitro-nitranilino)-ethane or 1,2-Bis-[N-4'-chloro-2',6'-dinitrophenyl)-nitramino]-ethane,* fine col crysts, mp 201-3°; was prepd by nitrating 1,2-bis(4'-chloro-2'-nitroanilino)-ethane or 1,2-bis(4'-chloro-2',6'-dinitroanilino)-ethane with abs nitric acid(Ref 2, p 554. Its expl props were not detd
**1,2•Bis(chloro•trinitro•nitranilino)•ethane** or *1,2-Bis[N-(chloro-trinitrophenyl)-nitramino]-ethane,*
$Cl(O_2N)_3C_6H.N(NO_2).CH_2.CH_2.N(NO_2).C_6H(NO_2)_3Cl$, mw 641.18, N 21.85%. One isomer is known: *1,2-Bis-(5'-chloro-2',4',6'-trinitro-nitranilino)-ethane* or *1,2-Bis[N-(5'-chloro-2',4',6'-trinitrophenyl)-nitramino]-ethane,* pale yel crysts, mp 170°, expl at higher temp; was prepd by nitrating 1,2-bis-(chloro-dinitro-nitraniline)-ethane with absol nitric acid at 0° (Ref 2,p 864)
*Refs*: 1)Beil- not found 2)A.E.Schouten,Rec **56**,547ff,554ff, & 863ff(1937); CA **31**, 5335 & 7045 (1937)

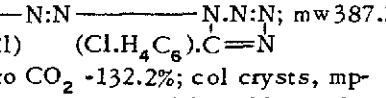
**Bis(chloroanilino)•propane and Derivatives**
*1,3-Bis(chloroanilino)-propane or 1,3-Bis[N-(chlorophenyl)-amino]-propane,*
$Cl.C_6H_4.NH.CH_2.CH_2.CH_2.NH.C_6H_4.Cl$. One isomer is described in Ref 2,p 1008
*1,3-Bis(chloro-nitroanilino)-propane,*
$Cl(O_2N)C_6H_3.NH.CH_2.CH_2.CH_2.NH.C_6H_3(NO_2)Cl$. One isomer is described in Ref 2,p 1010
**1,3•Bis(chloro•dinitroanilino)•propane,**
$Cl(O_2N)_2C_6H_2.NH.CH_2.CH_2.CH_2.NH.C_6H_2(NO_2)_2Cl$; mw 475.21, N 17.69%. One isomer is known: *1,3-Bis(4'-chloro-2',6'-dinitro-anilino)- propane* or *1,3-Bis[N-(4'-chloro-2',6'-dinitrophenyl)-amino]-propane,* yel crysts, mp 217°, expl mildly; was prepd by boiling an alc soln of 2,6-dinitro-4-chloro-anisole with 1,3-diaminopropane. May be nitrated to give more powerful expls described below(Ref 2,pp 1008 & 1013)
**1,3•Bis(4'•chloro•2',6'•dinitro•nitranilino)•propane** or *1,3-Bis[N-(4'-chloro-2',6'-dinitrophenyl)-nitramino]-propane,*
$Cl.(O_2N)_2C_6H_2.N(NO_2).CH_2.CH_2.CH_2.N(NO_2)-C_6H_2(NO_2)_2.Cl$; mw 565.21, N 19.82%; cream col scales, mp 159-61°; expl violently; sol in acet, dioxane, hot benz, toluene or chlf; insol in w, alc, eth, petr eth or $CCl_4$; can be prepd by nitration with abs nitric acid either 1,3-bis(4'-chloro-anilino)-propane or 1,3-bis(4'-chloro-2', 6'-dinitroanilino)-propane(Ref 2,pp 1008 & 1014)
**1,3•Bis(5'•chloro•2',4',6'•trinitro•nitranilino)•propane or** *1,3-Bis[N-(5'-chloro-2',4',6'-trinitrophenyl)-nitramino]-propane,*
$Cl.(O_2N)_3C_6H.N(NO_2).CH_2.CH_2.CH_2.N(NO_2)-C_6H(NO_2)_3.Cl$; mw 655.21, N 21.38%; crysts, mp 100°; expl violently; sol in acet, benz, toluene, chlf, AcOH & dioxane; sl sol in alc, eth & petr eth; insol in w; was prepd by nitration with abs nitric acid of 1,3-bis(5'-chloro-2'-nitroanilino)-propane(Ref 2,pp 1010-11 & 1014)
*Refs*: 1)Beil- not found 2)W.L.C.Veer,Rec **57**, 1008,1010-11 & 1013-14(1938) & CA **33**,1287-8 (1939)

**Bis(chloromethyl)thallium Chloride,** $(ClCH_2)_2$-TlCl; very unstable expl solid; was prepd by A. Ya Yakubovich & V.A.Ginsburg,DoklAkadN **73**, 957(1950) & CA **45**,2857(1951)

**1,2-Bis N-(5'-chlorophenyl)-amino-ethane.** See Bis(chloroanilino)-ethane

**1,2-Bis[N(4'-chlorophenyl)-amino]-propane.** See Bis(chloroanilino)-propane

**1,1'-Bis(o-chlorophenyl)-5,5'-azotetrazole** or *Azo-di[5-(o-chlorophenyl)-1-(a-tetrazole)]* (called Azo-1,1'-o-chlorophenyl-5.5'-tetrazol in Ger),



mw 387.20, N 36.18%, OB to $CO_2$ -132.2%; col crysts, mp-expl ca 122° or on impact; sol in cold concd $H_2SO_4$, from which it may be pptd with w; insol in w; nearly insol in common org solvs; can be prepd by treating 1,1-dichloroamino-5-(o-chlorophenyl)-*a*-tetrazole with aq KI soln followed by addn of an aq soln of a thiosulfate

*Refs*: 1)Beil- not found 2)R.Stollé et al,JPrakt Chem **138**,2 & 10-11(1933) & CA **27**,4798(1933) 3)F.R.Benson,ChemRevs **41**,16(1947)

**1,4-Bis(diazo)-butane,** $N_2CH.CH_2.CH_2.CHN_2$; mw 110.12, N 50.88%; yel, very unstable oil; was prepd by treating an ethereal soln of the bis-nitrosoureid, $[CH_2.CH_2.N(NO)CONH_2]_2$, with aq KOH at 0° and allowing it to react with benzoic acid, p-nitrobenzoic acid, phenol, *β*-naphthol or catechol(Refs 2 & 3). Samour & Mason(Ref 4) also prepd bis(diazo)-butane by this and other methods but they did not isolate the product, allowing it to react with carboxylic acids, aldehydes, acetone, phenol or ethyl acetoacetate

*Refs*: 1)Beil- not found 2)H.Lettré,Naturwissenschaften **36**,57(1949) & CA **44**,3892(1950) 3)T. Lieser & G.Beck,ChemBer **83**,140(1950) & CA **44**, 7233(1950) 4)C.M.Samour & J.P.Mason,JACS **76**, 441(1954) & CA **49**,3018(1955)

**4,4'-Bis(diazo)-3,3'-dioxy-biphenyl** [called 4.4'-Bis-diazo-3.3'-dioxy-diphenyl or Diphenyldichinon-(3,4,3',4')-bis-diazid-(4.4') in Ger],

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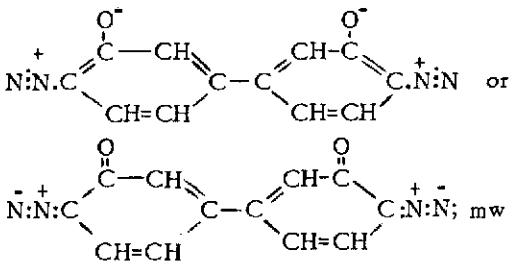


mw 238.20, N 23.52%; orn ndls, mp expl violently on heating; was prepd by diazotization of 4,4'-diamino-3,3'-dihydroxy-biphenyl or its disulfate in acid soln with $NaNO_2$

*Refs*: 1)Beil **16**, [292] 2)G.N.Burkhardt & H. Wood,JCS **1929**,149,151

**1,2-Bis(diazo)-ethane,** $N_2CH.CHN_2$; mw 82.07, N 68.28%; was prepd by adding NaOH or KOH to a cold, well-stirred abs alc soln of 1,2-bis-nitroso-ureidoethane, $(CH_2)_2[N(NO)-CONH_2]_2$. The product was not isolated but allowed to react in situ with an alc or eth soln of an acid or phenol

*Refs*: 1)Beil- not found 2)C.M.Samour & J.P. Mason,JACS **76**,442(1954) & CA **49**,3018(1955)

**Bis(diazo)-heptane,** $CH_2(CH_2CH_2CHN_2)_2$; mw 152.20, N 36.82%; orn-yel oil, very unstable; was prepd by nitrosation of $CH_2(CH_2.CH_2.CH_2.NHCOOC_2H_5)_2$, followed by treatment with cold KOH

*Refs*: 1)Beil- not found 2)T.Lieser & G.Beck, ChemBer **83**,141(1950) & CA **44**,7233(1950)

**1,6-Bis(diazo)-hexane,** $N_2CH(CH_2)_4CHN_2$; mw 138.17, N 40.55%; deep orn oil, dec spontaneously at 10° with evolution of N; cannot be distd in a high vacuum; was prepd from $H_2NCH_2(CH_2)_4CH_2NH_2$ as a starting material, the HCl salt of which, after adjustment with NaOH to a pH 9, was converted by reaction with aq KCNO to $H_2NCONH(CH_2)_4NHCONH_2$ and on nitrosation by reaction with $NaNO_2$ and treatment with well-cooled KOH below 0°, gave the desired product(Refs 3 & 4). Kirst(Ref 2) had earlier observed the definite tanning effect of this compd on limed animal hides, but he did not describe its prepn. Buckley & Ray(Ref 5) described and patented the use of bis(diazo)-hexane with ortho-borate esters at 0° to obt branched chain paraffins of high mw, and tough, flexible rubbery films (Ref 7). Samour & Mason(Ref 6) reported cross-linked products resulted from treating poly-acrylic acid or polymethacrylic acid with an alc soln of bis(diazo)-hexane. Expl props of the compd were not investigated

*Refs*: 1)Beil- not found 2)W.Kirst, Melliand Textilber **28**,169(1947) & CA **42**,8480(1948) 3)H.Lettré & U.Brosé,Naturwissenschaften **36**, 57(1949) & CA **44**,3892(1950) 4)T.Lieser & G. Beck,ChemBer **83**,138(1950) & CA **44**,7232(1950) 5)G.D.Buckley & N.H.Ray,JCS **1952**,3701 & CA

**47**,8006(1953); BritP 701203(1953) & CA **48**,9106 (1954); and USP 2671767(1954) & CA **48**,7342 (1954) 6)C.M.Samour & J.P.Mason,JACS **76**,444 (1954) & CA **49**,3019(1955) 7)N.H.Ray,USP 2670333(1954); BritP 709395(1954) & CA **49**,4007 (1955)

**1,5-Bis(diazo)-pentane,** $N_2CH(CH_2)_3CHN_2$; mw 124.15, N 45.13%; yel, very unstable oil; was prepd by nitrosation of $CH_2(CH_2CHNHCONH_2)_2$ to give $CH_2[CH_2CHN(NO)CONH_2]_2$ which on treatment with KOH gave the desired product. Its expl props were not investigated

*Refs*: 1)Beil- not found 2)H.Lettré & U.Brosé, Naturwissenschaften **36**,57(1949) & CA **44**,3892 (1950) 3)T.Lieser & G.Beck. ChemBer **83**,140 (1950) & CA **44**,7233(1950)

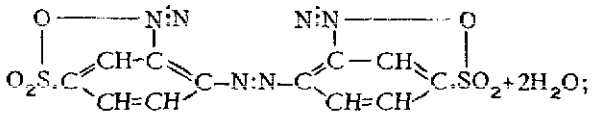
**Bis(p-diazophenol)-dichromate,** $(HO.C_6H_4.N_2)_2Cr_2O_7$; N 12.2%, crysts, mp- expl ca 134° when dry and pure; was prepd by diazotization of p-aminophenol followed by addn of a dichromate. It is fairly stable, but less so than the chromate obtd from p-phenylenediamine(Ref 2,pp 4-5). The same author prepd chromates of diazonium and nitrodiazonium derivatives of aniline, bromoaniline, chloroaniline, benzidine, p-phenylenediamine, etc and found them more or less expl when dry

*Refs*: 1)Beil- not found 2)R.Meldola,JCS **87** I, 4-5(1905)

**1,3-Bis(diazo)-propane,,** $N_2CH.CH_2.CHN_2$; mw 96.09, N 58.31%; very unstable oil; was prepd by treating 1 mol of $CH_2(CH_2.NH.CONH_2)_2$ in 2 mols $C_2H_5NO_2$ with HCl, neutralizing the mixt with $Na_2CO_3$ and washing the oil with w to give $CH_2[CH_2N(NO)CO_2C_2H_5]_2$ which, with KOH in NaCl-ice mixt, gave the product. Its expl props were not investigated

*Refs*: 1)Beil- not found 2)T.Lieser & G.Beck, ChemBer **83**,140(1950) & CA **44**,7233(1950)

**Bis(2-diazo-4-sulfenyl-N,S-oxy)-azobenzene.** [called 2,2'-Bis diazo-azobenzol-disulfonsäure -(4.4') in Beil(Ref 1) and Diazoverbindung des o-diamidoazobenzol-p-disulfonsäure by Zincke & Kuchenbecker(Ref 2)]



$O_2S.C_{12}H_6N_4.SO_2 + 2H_2O$;

mw 430.38, N 19.53%; yel pdr, mp expl violently on heating; sol in alkalies, giving a red soln; nearly insol in w or alc; was prepd by heating 2,2'-diaminoazobenzene-4,4'-disulfenic acid with alc, HCl and excess of ethyl nitrite

*Refs*: 1)Beil **16**,619 2)T.Zincke & A.Kuchenbecker,Ann **330**,21(1904)

**Bisdiazotetrazolylhydrazide.** See [N',$N^6$-Bis(α-tetrazolyl-5)]-hexazadiene, Vol 1,p 260-R, under Aminotetrazole

**1,2-Bis[N-(4',6'-dibromo-2'-nitrophenyl)-nitramino]-ethane,** $Br_2(NO_2)C_6H_2.N(NO_2).CH_2.CH_2.N(NO_2)-CH_2.CH_2.N(NO_2)C_6H_2(NO_2)Br_2$; mw 707.91, N 11.87%; pale yel ndls(from dil dioxane), mp 207°, expl mildly on heating to higher temp; sol in dioxane, boiling acet, benz toluene or chlf; insol in w, alc, eth, petr eth or $CCl_4$; was prepd by nitration of 1,2-bis(4',6'-dibromo-2'-nitrophenylamino)-ethane, previously obtd by reacting 1,3-dibromo-4,5-dinitrobenzene with ethylene diamine in alc soln

*Refs*: 1)Beil- not found 2)W.L.C.Veer,Rec **57**,1012 & 1014(1938)

**1,3-Bis[N-(4',6'-dibromo-2'-nitrophenyl)-nitramino]-propane,** $Br_2(NO_2)C_6H_2.N(NO_2).CH_2.CH_2.CH_2-N(NO_2)C_6H_2(NO_2)Br_2$;mw 721.94, N 11.64%; yel crysts(from dil dioxane), mp 199°, expl mildly on heating to higher temp; sol in dioxane, boiling benz, acet, chlf or toluene; insol in w, alc, eth, petr eth or $CCl_4$; was obtd on nitration of the 1,3-bis nitrophenylamino deriv previously prepd

*Refs:* Same as above

**1,2-Bis[N-(4',6'-dichloro-2'-nitrophenyl)-nitramino]-ethane,** $Cl_2(NO_2)C_6H_2.N(NO_2).CH_2.CH_2.N(NO_2)C_6H_2-(NO_2)Cl_2$; mw 530.08, N 15.86%; pale yel crysts (from dil dioxane), mp 196°, expl mildly on heating to higher temp; sol in dioxane, boiling acet, benz, toluene or chlf; insol in w, alc, eth or petr eth; was prepd by nitration of 1,2-bis(4',6'-dichloro-2'-nitrophenylamino)-ethane, previously obtd by reacting 1,3-dichloro-4,5-dinitrobenzene with ethylene diamine

*Refs*: 1)Beil- not found 2)W.L.C.Veer,Rec **57**, 1012 & 1014(1938)

**1,3-Bis[N-(4',6'-dichloro-2'-nitrophenyl)-nitramino]-propane,** $Cl_2(NO_2)C_6H_2.N(NO_2).CH_2.CH_2.CH_2.N(NO_2)-C_6H_2(NO_2)Cl_2$; mw 544.11, N 15.45%; almost col crysts(from alc+acet) contg 0.5 $C_2H_5OH$; mp 149°, expl mildly on heating to higher temp; sol in acet, benz, toluene, chlf or $CCl_4$; sl sol in alc; insol in eth or petr eth; was prepd by nitration of 1,3-bis(4',6'-dichloro-2-nitrophenylamino)-propane, previously obtd by heating an alc soln of 1,3-dichloro-4,5-dinitrobenzene and 1,3-diaminopropane

*Refs*: 1)Beil- not found 2)W.L.C.Veer,Rec **57**, 1014-15(1938)

**Bis(diethyl) Lead Styphnate, Basic,** $(O_2N)_3C_6H[OPb(CH_2{\cdot}CH_3)_2OH]_2$; mw 871.77, N 4.82%; yel crysts, mp expl ca 229°; was prepd by Burrows et al(Ref 2) by reacting diethyl lead dichloride and diammonium styphnate at RT. It detonates with a firing current of 0.31-0.36amps (vs 0.40-0.47amp for lead styphnate) and was proposed for use as an ignition compn in elec blasting caps

*Refs*: 1)Beil- not found 2)L.A.Burrows et al, USP 2105635(1938) & CA **32**,2357(1938)

**Bis(dihydroxypropyl)•oxamide and Derivatives**

*N,N'-Bis(2,3-dihydroxypropyl)-oxamide; N,N'-Di-(β,γ-dihydroxypropyl)-oxamide,* $[HO.CH_2CH(OH).CH_2.NHCO-]_2$; mw 236.22, N 11.86%; was obtd by the reactions:

$$\text{glycerin} \xrightarrow{HCl} \text{chlorohydrin} \xrightarrow{NaOH}$$

$$\text{glyceride} \xrightarrow{NH_3} H_2N{\cdot}CH_2{\cdot}CH(OH){\cdot}CH_2OH$$

$$\xrightarrow{(C_2H_5)_2C_2O_4} [HO{\cdot}CH_2{\cdot}CH(OH){\cdot}CH_2{\cdot}NH{\cdot}CO]_2$$

On nitration it yields the following expl deriv(Ref 2):

**N,N'•Bis(2,3•dihydroxypropyl)•oxamide Tetra•nitrate** or *N,N'-Di(β,γ-dihydroxypropyl)-oxamide Tetranitrate* listed in CA Coll Formula Index (1920-1946),p 281 as $C_8H_{18}N_6O_{14}$ or $\underset{\text{CO.NH.CH}_2\text{.CH(HONO}_2\text{).CH}_2\text{(HONO}_2\text{)}}{\text{CO.NH.CH}_2\text{.CH(HONO}_2\text{).CH}_2\text{(HONO}_2\text{)}}$; mw 420.26, N 20.00; listed in Blatt as a compd of empirical formula $C_8H_{12}N_6O_{14}$ or $\underset{\text{CONHCH}_2\text{CH(ONO}_2\text{)CH}_2\text{(ONO}_2\text{)}}{\text{CONHCH}_2\text{CH(ONO}_2\text{)CH}_2\text{(ONO}_2\text{)}}$; mw 416.22, N 20.19%, OB to $CO_2$ -30.8%; mp 142.5°, expl on heating to 178°; was prepd by nitrating the parent compd with a mixt of $HNO_3$ and $H_2SO_4$ below 10°. This compd is a powerful expl of high stability. Its props resemble those of N,N'-dinitro-N,N'-dimethyl-oxamide, $O_2N(CH_3)N.CO.CO.N(CH_3)NO_2$

Blatt(Ref 3) lists the following expl props as reported in Ref 2: *Impact Sensitivity*, 2kg wt, positive at 60cm vs 60-80cm for TNT; *Lead Block Expansion*, 325cc vs 266cc for TNT at d 1.1; *Thermal Stability*, no decompn at 70° for 200hrs; *Velocity of Detonation*,4030m/sec in paper tubes at d 0.62

*Refs*: 1)Beil- not found 2)T.Domanski & J. Skudrzyk,RoczChem **19**,2127(1939) & CA **34**, 4056(1940) 3)Blatt,OSRD **2014**(1944)

**Bis(1,3•dimethylamino)•benzene.** Same as N,N,-N',N'-Tetramethyl-m-phenylenediamine

**Bis(dimethylamino)•triphenylmethane and Derivatives**

*Bis(dimethylamino)-triphenylmethane or Tetramethyl-diamino-triphenylmethane,* $C_{23}H_{26}N_2$. Three isomers are described in Beil **13**,273-5, (89) & [135]

*Mononitro-bis(dimethylamino)-triphenylmethane,* $C_{23}H_{25}N_3O_2$. Three isomers are described in Beil **13**,278-80 & [136]

*Dinitro-bis(dimethylamino)-triphenylmethane,* $C_{23}H_{24}N_4O_4$. Two isomers are described in Beil **13**,280 & [137]

*Tri-, Tetra- and Pentanitro Derivatives*, were not found in Beil or in CA thru 1956

**Hexanitro•4,4'•bis(dimethylamino)•triphenyl•methane,** $(CH_3)_2N.(O_2N)_3C_{19}H_8(NO_2)_3.N(CH_3)_2$; mw 600.45, N 18.66%; golden-yel ndls(from AcOH), mp 200° (dec); fairly sol in alc, acet & AcOH especially on warming; was prepd by treating 4,4'-bis(dimethylamino)-triphenylmethane, $(CH_3)_2N.C_6H_4.\underset{C_6H_5}{CH}.C_6H_4.N(CH_3)_2$, with fuming nitric acid(d 1.4)(Refs 1,2 & 3). It expl sharply on sudden heating(Ref 3)

*Refs*: 1)Beil **13**,280-1 2)O.Fischer,Ber **11**,950 (1878) 3)Ibid,Ann **206**,128(1881)

**Bis(1,1•dimethyl•2•propynyl) Peroxide.** See Vol 1, p A66-R

**1',2'•Bis(2,2•dinitroalkyl)•amines** of general formula $[R(NO_2)_2C.CH_2]_2NH$ were prepd recently in Sweden by treating 2,2-dinitroalkyl-1-ethanol with 2,2-dinitroalkyl-1-amine: $R(O_2N)_2C.CH_2.OH + H_2N.CH_2.C(NO_2)R = [R(O_2N)C.CH_2]_2NH + H_2O$. Some of these compds may be suitable as ingredients of expl and propellant compositions

*Refs*: 1)Beil- not found 2)F.R.Schenck & G.A. Wetterholn,SwedP 148217(1954); BritP 729469 (1955); USP 2731460(1956) & CA **50**, 1893,7125 (1956)

**N,N'•[Bis•(2,2•dinitroalkyl)•hydrazines]** of general formula $R(O_2N)_2C.CH_2.HN.NH.CH_2C(NO_2)R$ were prepd recently in Sweden by the action of 1 mol hydrazine on 2 mols of 2,2-dinitroalkyl-1-ethanol:

$2R(O_2N)_2C.CH_2OH + H_2N.NH_2 = 2H_2O + [R(O_2N)_2C.CH_2.NH-]_2$

Some of these compds are suitable as ingredients of expl and propellent compositions

*Refs*: 1)Beil- not found 2)F.R.Schenck & G.A. Wetterholn,SwedP 148217(1954); BritP 729469 (1955); USP 2731469(1956) & CA **50**,1893 & 7125(1956)

**Bis(dinitrobenzoyl)•peroxide.** See Di(dinitrobenzoyl)-peroxide under Dibenzoylperoxide

**2,2'•Bis(3,5•dinitro•4•hydroxyphenyl)•propane.** See under Bis(hydroxyphenyl)-propane

**Bis(3,5•dinitro•4•hydroxyphenyl)•sulfone.** See under Bis(hydroxyphenyl)-sulfone

**Bis(2,4•dinitrophenyl)•disulfide.** See 2,4,2',4'-Tetranitrodiphenyl-disulfide under Diphenyldisulfide

**1,3'•Bis(1,3-dinitroxy•2•nitramino-propane)-2',4',6'•trinitrobenzene.** See Vol 1,p A252-L

**1,3•Bis(2,3•dinitroxy•1•nitramino•propane)•2',4',6'•trinitrobenzene.** See Vol 1,p A252-R

**Bis(diphenylcarbamide)-Ethylenediamine Complex.** See under Diphenylcarbamide Complexes Suitable as Stabilizers and Gelatinizers in Smokeless Propellants

**Bis•diphenylurea** (called Bis diphenylurée in Fr and N.N'-Bis diphenylaminoformyl-hydrazin in Ger), $(C_6H_5)_2N.CO.NH.NH.CO.N(C_6H_5)_2$; mw 422.47, N 13.26%; col crysts, mp 215-217°, giving a wh vapor; $Q_c^v$ 3214kcal/mol; $Q_f^v$ -14.6kcal/mol; sol in acet; sl sol in cold w, alc or chlf; was prepd by reacting 1 mol of hydrazine hydrate with 2 mols of diphenylcarbamic acid chloride (Refs 1 & 2). This compd was claimed by Tavernier & Lamouroux(Ref 3) as one of a number of org derivs suitable for incorporation in smokeless propellants
*Refs*: 1)Beil **12**,(258) 2)B.Toschi,Gazz **44**, 445(1914) & JCS **106** I,740(1914) 3)P.Tavernier & M.Lamouroux,MP **38**,73 & 83(1956) & CA **51**, 14403(1957)

**1,3•Bis(β•ethanolamino)•benzene.** Same as 1,3-Bis(β-hydroxyethylamino)-benzene, described under 1,3-Di(β-ethylolamino)-benzene

**N,N'•Bis(β•ethanol)•ethylenediamine.** Same as 1,2-Bis(β-hydroxyethylamino)-ethane, described under 1,2-Di(β-ethylol)-ethylenediamine

**N,N'•Bis(β•ethanol)•oxamide.** Same as N,N'-Bis(β-hydroxyethyl)-oxamide, described under N,N'-Di(ethylol)-oxamide

**N,N'•Bis(β•ethanol)•sulfamide.** Same as N,N'-Bis(β-hydroxyethyl)-sulfamide, described under N,N'-Di(ethylol)-sulfamide

**Bis(ethylamine).** Same as Diethylamine

**Bis(ethyl)•ethylenediamine.** Same as Diethylethylenediamine

**Bis(ethylhexyl)•phthalate,** $C_6H_4[COO.CH(C_2H_5).CH_2.CH_2.CH_2.CH_3]_2$; mw 390.54; col liq, d 0.984 at 21°, $n_D$ 1.48691 at 25°, $Q_c^v$ 3298.2kcal/mol and $Q_f^v$ 252.6kcal/mol; miscible with alc, eth, acet and many other org solvents. It was suggested as a possible component of propellants
*Refs*: 1)Beil- not found 2)P.Tavernier & M. Lamouroux,MP **37**,203 & 206(1955)

**Bis(ethyl)•hydrazine.** Same as Diethylhydrazine

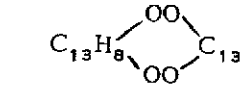
**Bis(ethylnitrosamino)•azoxybenzene,** $C_2H_5.N(NO)-C_6H_4.N_2O.C_6H_4.N(NO).C_2H_5$; 342.35, N 24.55%; yel ndls(from alc), mp 171°; was obtd on treating ethyl-(4-nitrosophenyl)-nitrosamine in alc soln with Na amalgam. Its expl props were not investigated
*Refs*: 1)Beil **16**,655 2)O.Fischer,Ann **286**,158 (1895)

**1,3•Bis(ethyltriazeno)•benzene or** *3,3'-m-Phenylene-bis(1-ethyltriazene),* $H_5C_2.HN.N:N.C_6H_4.N:N.NH.C_2H_5$; mw 220.28, N 38.16%; yel crysts(from alc), mp 104°, expl on sudden heating; easily sol in acet, eth or chlf; diffc sol in ligroin or toluene; decomp violently by AcOH. Was prepd by the action of ethylmagnesium bromide on 1,3-diazobenzene in ether
*Refs*: 1)Beil **16**, [356] 2)H.Kleinfeller,JPrakt-Chem **119**,65(1928) & CA **22**,2566(1928)

**N,N'•Bis(5•ethyl•s•triazol•3•yl)•formamidine or 3,3'•Bis(5•ethyl•1H•1,2,4•triazolyl)•formamidine,** $H_5C_2.\underset{\underset{N}{\|}}{C}-N=\underset{\underset{NH}{|}}{C}-N:CH.NH-\underset{\underset{HN}{|}}{C}=N-\underset{\underset{N}{\|}}{C}.C_2H_5$; mw 234.27, N 47.84%; wh rhombs, mp 263°; was prepd by boiling for 2 hrs, 2 mols of 3-amino-5-ethyl-s-triazole with an excess(over 1 mol) of ethylorthoformate, followed by cooling. This high-nitrogen compd was patented as a stabilizer for photographic emulsions. Its expl props were not investigated
*Refs*: 1)Beil- not found 2)J.D.Kendall & H.G.Suggate,USP 2534914(1950) & CA **45**, 2350(1951) 3)Ibid,USP 2588538(1952) &

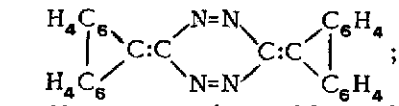
CA **46**,4405-6(1952)

**9,9'-Bis(fluorenyl)-diperoxide** {called *Dispiro [fluorene-9,3'-s-tetroxane-6',9"-fluorene]* in CA Formula Index for 1950 and "Dimeres Fluorenonperoxyd" in Ref 2}

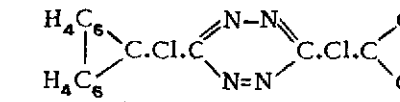


$C_{13}H_8$; mw 392.39, O 16.31%; lt yel prisms(from dioxane or tetrahydrofurane), mp 203° with decompn; expl mildly when heated in a tube; was obtd on treating the adduct 9,9'-bis-(hydroperoxy)-fluorene+2Fluorenones, $C_{39}H_{26}O_6$, with N/10 Pb acetate soln in AcOH(Ref 2,p 21)
*Refs*: 1)Beil- not found 2)R.Criegee et al,Ann **565**,15 & 21(1949); CA **44**,1918(1950)

**3,6-Bis(fluorenylidenehydro)-sym-tetrazine** or *Bis(diphenylenemethylene)-dihydrotetrazine* (called 3,6-Difluorenyliden-3,6-dihydro-1.2.4.5 -tetrazin in Ger),

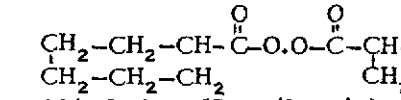


; mw 408.44, N 13.72%; grn prisms with metallic luster(from benz), mp- expl mildly ca 240°; sol in benz; sl sol in eth acet; nearly insol in alc or eth; can be prepd by shaking at RT 3,6-bis(9-chloro or bromo-9 -fluorenyl)-1,2,4,5-tetrazine,



, with benzolic suspension of Hg. Other props & methods of prepn are given in the Refs
*Refs*: 1)Beil **26**,(120) 2)R.Stollé et al,Ber **46**, 235(1913) 3)J.Lifschitz,Ber **48**,415-16(1915)

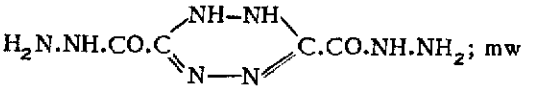
**Bis(hexahydrobenzoyl)-peroxide or Bis(cyclohexanecarbonyl)-peroxide** (called di-hexahydrobenzoyl-peroxyd by Fichter & Siegrist),



mw 254.32, O 25.17%; oil evolving $CO_2$ at RT; large quants can expl without apparent reason; was obtd when the anhydride of cyclohexane carboxylic acid in abs eth was shaken with 93% of the calcd quant of finely powd $BaO_2.8H_2O$. Rapid concn of the eth soln in vacuo yielded the desired product
*Refs*: 1)Beil- not found 2)F.Fichter & W. Siegrist,Helv **15**,1304(1932) & CA **27**,279(1933) 3)Tobolsky & Mesrobian(1954),179

**Bishydrazicarbonyl or Diurea.** See Note under 4 -Aminourazole, Vol 1,p A272-L

**3,6-Bis(hydrazide)-1,2-dihydro-1,2,4,5-tetrazine** [called the Dihydrazid of 1.2-Dihydro-1.2.4.5 -tetrazin-dicarbonsäure-(3.6) in Ger],



mw 200.17, N 55.99%; yel crysts(from w), mp ca 265-275° (dec); sol in 800p boiling w; was obtd in an impure state by heating the diethylester of 1,2-dihydro-1,2,4,5-tetrazine-3,6-dicarboxylic acid with an excess of hydrazine hydrate or anhyd hydrazine

Its *Hydrochloride*, $C_4H_8N_8O_2$+2HCl, small violet-red crysts, exploded violently on heating
*Refs*: 1)Beil **26**,570 2)T.Curtius & E.Rimele, Ber **41**,3113-3114(1908) & CA **3**,67(1909)

**Bis(hydrazino)-dinitrobenzene and Derivatives**

**1,3-Bis(hydrazino)-4,6-dinitrobenzene** called [4.6-Dinitro-1.3-dihydrazino-benzol or 4.6-Dinitro -phenylendihydrazin-(1.3) in Ger], $(H_2N.NH)_2C_6H_2(NO_2)_2$; mw 228.17, N 36.84%; brn ndls(from nitrobenz), mp 310°(decompg with a flash); other props and methods of prepn are given in Ref 1. This compd may be considered as the parent compd of the following unstable derivs:

*1,3-Bis(benzylidenehydrazino)-4,6-dinitrobenzene*, $(C_6H_5.CH:N.HN)_2C_6H_2(NO_2)_2$; mw 404.38, N 20.78%; red lfts(from nitrobenz), mp 302-304° (dec); mod sol in boiling nitrobenz; insol in alc or AcOH; was prepd by heating 1,3-bis(hydrazino) -4,6-dinitrobenzene with benzaldehyde in aq alc HCl or nitrobenzene(Refs 1 & 2,p 681)

*1,3-Bis(diphenylmethylenehydrazino)-4,6-dinitrobenzene*, $[(C_6H_5)_2C:N.NH]_2C_6H_2(NO_2)_2$; mw 556.56, N 15.10%; yel ndls(from nitrobenz), mp becomes brn ca 280°, dec 305°; mod sol in nitrobenz; almost insol in alc or AcOH; was prepd by heating 1,3-bis(hydrazino)-4,6-dinitrobenzene with benzophenone in aq alc HCl, followed by addn of a Na acetate salt(Refs 1 & 2,pp 671, 682)

*1,3-Bis(isopropylidenehydrazino)-4,6-dinitrobenzene*, $[(H_3C)_2C:N.NH]_2C_6H_2(NO_2)_2$; mw 308.30, N 27.26%; orn ndls(from AcOH or et acet), mp 234-235°(dec); was prepd by heating acetone with 1,3-bis(hydrazino)-4,6-dinitrobenzene in aq alc HCl(Refs 1 & 2,p 681)

*1,3-Bis(methylenehydrazino)-4,6-dinitrobenzene*, $(H_2C:N.NH)_2C_6H_2(NO_2)_2$; mw 252.19, N 33.33%;

yel ndls(from alc or nitrobenz), mp 247°(dec); sol in boiling nitrobenz; diffc sol in boiling AcOH; almost insol in alc; was prepd by treating 1,3-bis(hydrazino)-4,6-dinitrobenzene in boiling alc HCl with formaldehyde, followed by addn of Na acetate(Refs 1 & 2,p 680)

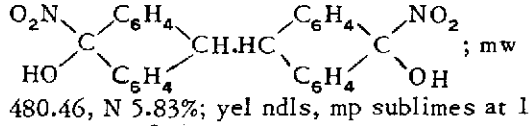
*1,3-Bis(β-phenylhydrazino)-4,6-dinitrobenzene*, $(C_6H_5.NH.HN)_2C_6H_2(NO_2)_2$; mw 380.36, N 22.10%; orn-red crysts(from acet+alc), mp 211-212°(dec); sol in acet or chlf; diffc sol in alc or eth; was obtd, together with 5-chloro-2,4-dinitrohydrazobenzene, by the action of phenylhydrazine on 5-chloro-1,2,4-trinitrobenzene(Refs 1 & 3)

*Refs*: 1)Beil **15**,[266] 2)W.Borsche,Ber **54**,671, 680-682(1921) & JCS **120** I,461(1921) 3)M.Giua, Gazz **51**,312(1921) & JCS **120** I,551(1921)

### Bis(hydroanthranol) and Derivatives

*Bis(hydroanthranol)*, $C_{28}H_{22}O_2$, mw 390.46, O 8.19%; although not described in the literature, may be considered as the parent compd of its nitro and nitrate derivs, although they were not prepd from it

**Bis(nitrohydroanthranol)** or *9,9'-Dinitro-9,9'-dihydroxy-10,10'-dihydroanthracene*[called 10.10'-Dinitro-10.10'-dioxy-9.10.9'.10'-tetrahydro-dianthranyl-(9.9') in Ger],

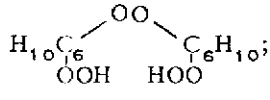


; mw 480.46, N 5.83%; yel ndls, mp sublimes at 120°, dec 267-268°; burns explosively at higher temps or in contact with a flame; sl sol in alc, eth or benz; dec in hot dil NaOH; was prepd by adding $HNO_3$ dropwise to a mixt of pure anthracene in AcOH and acet at 7-8° during 2 hrs, and heating to 50-55° after standing at RT for two days(Refs 1 & 3)

Its *Dinitrate*, $C_{28}H_{22}N_4O_{10}$, mp 290°, resembling bis(nitrohydroanthranol) in all other props, was obtd when the product of nitration was heated to 50-55° after 3 hrs standing at RT(Refs 2 & 3)

*Refs*: 1)Beil **7**,[797] 2)Beil **5**,[572] 3)J.S. Turski & A.Berlandstein,RoczChem **7**,457(1927) & CA **22**,3159(1928)

**1,1'-Bis(hydroperoxycyclohexyl)-peroxide or 1,1'-Bis(hydroperoxy)-dicyclohexyl Peroxide,**



; mw 262.30, O 36.60%; col prisms(from dil AcOH) or ndls(from hot w), expl when heated in a flame; was prepd by treating cyclohexanone with an ethereal soln of $H_2O_2$ in the cold(Ref 2,p 17 & Ref 3)

Its *Acetone Compound* {called "Isopropyliden-di-cyclohexyliden-triperoxyd" in Ger(Ref 2,p 11) and *17,17-Dimethyl-7,8,15,16,18,19-hexoxadispiro-[5.2.5.5]-nonadecane* in CA Formula Index for 1950}, $H_{10}C_6(OO)_2C_6H_{10}$; mw 302.36, O 31.75%; col crysts(from methanol), mp 64°; expl by heat or friction; was obtd by allowing a mixt of 1,1'-bis(hydroperoxycyclohexyl)-peroxide, anhyd acetone and anhyd Cu sulfate to stand for 14 days(Ref 2,p 18)

*Refs*: 1)Beil- not found 2)R.Criegee et al,Ann **565**,8 & 17-18(1949); CA **44**,1917(1950) 3)Tobolsky & Mesrobian(1954),179

**Bis(hydroperoxy)-dicyclohexyl Peroxide.** Same as 1,1'-Bis(hydroperoxycyclohexyl)-peroxide

**2,5-Bis(hydroperoxy-2,5-dimethyl)-hexane**[called *(1,1,4,4-Tetramethyltetramethylene)-dihydroperoxide* in CA Formula Index]



; mw 178.22, O 35.91%; prisms(from w or benz), mp 104-5°; expl in flame but not by friction; was prepd by treating anhyd tetramethyl-1,4-butanediol with 75% hydrogen peroxide(Ref 2,p 141)

Its *Acetone Compound*(called *3,3,6,6,9,9-Hexamethyl-1,2,4,5-tetroxonane* in CA 5th Decennial Formula Index),$(CH_3)_2C(OO)_2C(CH_3)_2$; mw 218.29, O 29.32%; crysts(from methanol), mp 42-3°; expl at higher temp; was obtd by allowing a mixt of 2,5-bis(hydroperoxide)-2,5-dimethylhexane, anhyd acetone and anhyd Cu sulfate to stand for 14 days(Ref 3,p 18)

Benzolation of 2,5-bis(hydroperoxy-2,5-dimethyl)-hexane yielded the *Dibenzoate*, $C_{22}H_{26}O_6$, fine pltlts(from MeOH), mp 117°, exploding when heated in a flame. Also, there was prepd the *Di-p-nitrobenzoate*, $C_{22}H_{24}N_2O_{10}$, lt yel lfts, mp 150°, exploding on heating in a flame(Ref 2)

*Refs:* 1)Beil- not found 2)R.Criegee & H.Dietrich, Ann **560**,141(1948) & CA **43**,6190(1949) 3)R. Criegee et al,Ann **565**,18(1949) & CA **44**,1917 (1950)

**9,9'-Bis(hydroperoxy)-fluorene+2Fluorenones (Adduct)** (formerly misnamed "Fluorenon-oxoxyd" in Ger)(listed as *"Fluorenone Compound with 9-Fluorenylidenedihydroperoxide"* in CA Formula Index for 1950),

$C_{13}H_8(OO.H)_2 + 2C_{13}H_8O$; mw 590.60, O 16.25%,

yel crysts(from hot benz or toluene), mp 108-108.5°; expl when heated on a spatula or brought in contact with concd sulfuric acid. It was first prepd by Wittig & Pieper on treating fluorenone with an ethereal soln of $H_2O_2$ in the presence of $P_2O_5$ (Ref 2). They claimed that the resulting peroxide had the formula $C_{13}H_8O_2$ and called it "Fluoran-peroxyd". Criegee et al(Ref 3) claimed that the compd prepd by W & P was not fluorenone peroxide but the adduct shown in this item

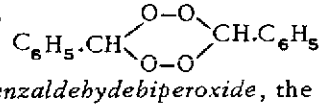
When heated at 85-90° and 0.01 mm Hg, this complex yielded fluorene and the adduct, $C_{39}H_{26}O_7$(1 mole fluorenone and 1 mole $H.OO.C_{13}H_8.OO.C_{13}H_8.OOH$), lt yel crysts, mp 134-5°, expl in flame(Ref 3,p 21)

Benzolation of 9,9-bis(hydroxyfluorenyl)-peroxide, called "Peroxyd XX" by Criegee, $HOO.C_{13}H_8.OO.C_{13}H_8.OOH$),gave the *Peroxybenzoic Acid Diester*, $C_6H_5.COO.C_{13}H_8.OO.C_{13}H_8.COO.C_6H_5$, col crysts(from benz), mp 135°, frequently detonating (Ref 3,p 21)

*Refs*: 1)Beil- not found 2)G.Wittig & G.Pieper, Ber **73**,296-7(1940) 3)R.Criegee et al,Ann **565**, 14 & 20-1(1949) & CA **44**,1917(1950)

**Bis(α-hydroxybenzyl)-peroxide** [called Bis-[α-oxy-benzyl]-peroxyd; α,α'-Dioxy-dibenzylperoxyd or Dibenzalperoxydhydrat in Ger], $C_6H_5.CH(OH).O.O.CH(OH).C_6H_5$; mw 246.25, O 25.99%; crysts(from benz), mp 60-62°; insol in w, cold eth or petr eth; was prepd by treating benzaldehyde with $H_2O_2$ below 30°(Ref 2). See also Refs 1,4,5 & 6

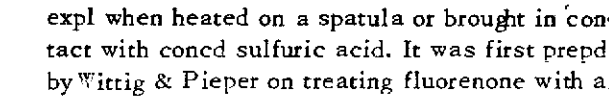
Either in the solid state or when treated with Na carbonate, it is dissociated into benzaldehyde and $H_2O_2$; cold acetic anhydride converts it into acetic peroxide, acetic acid and benzaldehyde (Refs 1 & 2). On adding benzaldehyde to a dil alc soln of $H_2O_2$ and $H_2SO_4$, Baeyer & Villiger (Ref 3) obtd a product,



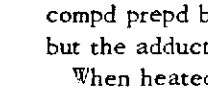
which they called *dibenzaldehydebiperoxide*, the inner anhydride of the compd obtd by Nef(Ref 2)

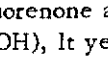
*Refs*: 1)Beil **7**,210 & [161] 2)J.U.Nef,Ann **298**, 292(1897) & JCS **74** I,110(1898) 3)A.Baeyer & V.Villiger,Ber **33**,2484(1900) 4)F.Fichter & E. Uhl,Helv **3**,37(1920) & JCS **118** I,234(1920) 5)C.S.Marvel & V.Nichols, JOC **6**,296(1941) & CA **35**,3997(1941) 6)Tobolsky & Mesrobian (1954),171

**Bis(1-hydroxycyclohexyl)-peroxide** or *1,1'-Dihydroxy-dicyclohexyl-1,1'-peroxide* (called Di-cyclohexanon-peroxyhydrat by Stoll & Scherrer),



mw 230.30, O 27.79%; col ndls, mp 68-70°, expl violently on attempting to purify it by vac distn; was prepd by treating cyclohexanone with $H_2O_2$. When treated with dil $H_2SO_4$ it gave an intermediate product



, called, *1-hydroxycyclohexylhydroperoxide* in Ref 5,p 171 and with concd $H_2SO_4$ it gave *cyclohexanone monoperoxide*,  (Ref 2,pp 143-4 & 149)

*Refs*: 1)Beil-not found 2)M.Stoll & W.Scherrer, Helv **13**,142-4 & 146-9(1930); CA **24**,2732(1930) 3)N.A.Milas et al,JACS **61**,2431(1939) 4)R. Criegee et al,Ann **565**,7(1949) & CA **44**,1917(1950) 5)Tobolsky & Mesrobian(1954),171 & 179 6)N. Brown et al, JACS **77**,1759(1955) 7)L.Horner & W.Jurgeleitt,Ann **591**,150(1955) & CA **50**,2498 (1956)

**Bis(hydroxyethoxy)-benzene and Derivatives**

*1,3-Bis(2-hydroxyethoxy)-benzene or Di-β-hydroxyethyl-m-phenylene Ether* [called Resorcin-bis-(β-oxy-äthyläther) in Ger], $C_6H_4(OCH_2.CH_2.OH)_2$; mw 198.21, O 32.29%; col crysts, mp 81°; sol in alc or methylethyl ketone; insol in eth, benz or ligroin; was prepd by treating resorcinol, in Na ethylate soln, with ethylene chlorhydrin(Refs 1 & 2). This may be considered the parent compd of its nitrated derivs

*Refs*: 1)Beil **6**, [816] 2)R.E.Rindfusz et al, JACS **42**,163(1920)

*1,3-Bis(2-hydroxyethoxy)-mononitrobenzene*, $C_{10}H_{13}NO_6$, not found in Beil or in CA thru 1956

**1,3-Bis(2-hydroxyethoxy)-4,6-dinitrobenzene** [listed in CA Coll Formula Index,p 424 & 5th Decennial Formula Index,p 578F, as *2,2'-(4,6-Dinitro-m-phenylenedioxy)-diethanol* and in Abstract as *4,6-Dinitroresorcinol-bis(or di)(2-hydroxyethyl)-ether*] [called 4,6-Dinitrophenyl-1,3-di(β-hydroxyethyl ether by Blanksma & Fohr and 4,6-Dinitro-resorcin-di-oxäthyl-äther in Ger

by Ruggli & Straub],$(O_2N)_2C_6H_2(OCH_2.CH_2.OH)_2$; mw 288.21, N 9.72%; col lfts(from w), mp 135°; readily sol in alc, AcOH or boiling w; mod sol in eth acet; diffc sol in eth, benz or chlf; was prepd by adding monosodium glycolate to a mixt of 1,3-dichloro-4,6-dinitrobenzene and glycol(Ref 2 & 3)

Its ester, *1,3-Bis(2-hydroxyethoxy)-4,6-dinitrobenzene Dinitrate*,$(O_2N)_2C_6H_2(OCH_2.CH_2.ONO_2)_2$; col ndls(from alc), mp 116°, dec 170°, ignites at 275°; readily sol in alc, benz, chlf or acet; sl sol in w, eth or light petroleum; was obtd by dissolving the compd in $HNO_3$ and pptg the product by pouring on ice(Ref 3)

**1,3-Bis(2-hydroxyethoxy)-2,4,6-trinitrobenzene Dinitrate** [listed in CA Coll Formula Index,p 545F, as *2,2'(2,4,6-trinitro-m-phenylenedioxy)-diethanol Dinitrate* and in Abstract as *2,4,6-Trinitro-1,3-bis(2-hydroxyethoxy)-benzene Dinitrate*] [called 2,4,6-Trinitrophenyl-1,3-di(β-hydroxyethyl ether) Dinitrate by Blanksma & Fohr]; $(O_2N)_3C_6H(OCH_2.CH_2.ONO_2)_2$; mw 423.31, N 16.55%; col ndls of bitter taste(from alc), mp 75°, dec 175°, ignites and expl 265°; readily sol in acet or benz; mod sol in alc, eth or chlf; v sl sol in w or light petroleum; was obtd on nitration of 1,3-bis(2-hydroxyethoxy)-4,6-dinitrobenzene dinitrate by dissolving it in anhyd $HNO_3$ & concd $H_2SO_4$ and pptg the product by pouring the soln on ice(Ref 3). On boiling this compd with caustic soda in aq soln, there was obtained 2,4,6-Trinitroresorcinol

*Refs*: 1)Beil- not found 2)P.Ruggli & O.Straub, Helv **21**,1099(1938) & CA **33**,1327(1939) 3)J.J. Blanksma & P.G.Fohr,Rec **65**,816-818(1946) & CA **41**,2704(1947)

**Bis(hydroxyethyl)-amine.** See Di(ethylol)-amine and Derivatives

**Bis(β-hydroxyethylamino)-benzene.** See 1,3-Di(β-ethylolamine)-benzene

**Bis(β-hydroxyethylamino)-ethane.** See 1,2-Di(β-ethylol)-ethylene diamine

**Bis(2-hydroxyethyl)-ammonium Nitrate.** See Di-(ethylol)-ammonium Nitrate

**N,N'-Bis(2-hydroxyethyl)-N,N'-dinitroxamide,** designated as **NENO**, is described under Di(ethylol)-oxamide

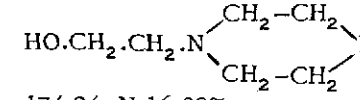
**Bis(2-hydroxyethyl)-ethylenediamine.** See N,N'-Di(2-ethylol)-ethylenediamine

**Bis(β-hydroxyethyl)-oxamide.** See Di(ethylol)-oxamide

**Bis(β-hydroxyethyl)-peroxide.** See Di(ethylol) peroxide

**Bis(hydroxyethyl)-piperazine and Derivatives**

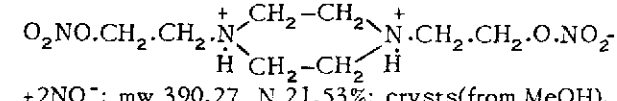
*N,N'-Bis(2-hydroxyethyl)-piperazine or N,N'-Di(2-ethylol)-piperazine* [called N.N'-Bis(β-oxy-äthyl)-piperazin in Ger],



HO.$CH_2$.$CH_2$.N(-$CH_2$-$CH_2$-)N.$CH_2$.$CH_2$.OH; mw 174.24, N 16.08%; tetrg pyramid crysts(from alc), mp 134-135°; very sol in w; sol in chlf; diffc sol in other org solvs; was prepd by heating piperazine with ethylene chlorohydrin at 105°. This compd forms numerous salts, such as *Hydrochloride, Hydrobromide, Nitrate.* The *Auric Chloride* or *Gold Trichloride,* $C_8H_{18}N_2O_2+2HCl+2AuCl_3$, forms lt yel ndls(from dil HCl), mp 205-207° (dec); and the *Picrate*, yel ndls(from alc), mp 245-246° (dec)

*Refs*: 1)Beil **23**,10 2)F.L.Pyman,JCS **93** II,1802 (1908)

**N,N'-Bis(2-nitroxyethyl)-piperazine Dinitrate,**



$O_2NO.CH_2.CH_2.N^+H(-CH_2-CH_2-)N^+H.CH_2.CH_2.O.NO_2^-$ $+2NO_3^-$; mw 390.27, N 21.53%; crysts(from MeOH), mp 129°; was prepd by nitrating N,N'-bis(2-hydroxyethyl)-piperazine with 98% $HNO_3$ below 10° and pptg the product by pouring on ice. This compd and related compds were investigated in the search for semi-expl plasticizers for flashless propellant powders

*Refs*: 1)Beil- not found 2)A.T.Blomquist,OSRD **5155**(1945),p 129

**N,N'-Bis(hydroxyethyl)-propyleneamine.** See N,N'-Di(ethylol)-propyleneamine

**N,N'-Bis(hydroxyethyl)-propylenedinitramine.** See N,N'-Di(ethylol)-propylenedinitramine under N,N'-Di(ethylol)-propyleneamine

**Bis(β-hydroxyethyl)-sulfamide.** See Di(ethylol)-sulfamide

**Bis(hydroxylamino)-azide.** See Vol 1,p A525-L

**N,N'-Bis(β-hydroxymethyl)-amine.** See Di(methylol)-amine

**N,N'-Bis(β-hydroxymethyl)-benzene.** See Di-(methylol)-benzene

**2,6-Bis(hydroxymethyl)-2,6-dinitro-1,7-heptanediol Tetranitrate.** See 2,6-Dimethylol-2,6-dinitro-1,7-heptanediol Tetranitrate

**2,5-Bis(hydroxymethyl)-2,5-dinitro-1,6-hexanediol Tetranitrate.** See 2,5-Dimethylol-2,5-dinitro-1,6-hexanediol Tetranitrate

**Bis(hydroxymethylether)-peroxide.** See Di(methylol)-di(oxymethylene)-peroxide

**Bis(hydroxymethyl)-ethylenediamine.** See Di-(methylol)-ethylenediamine

**Bis[(hydroxymethyl)-2-methoxy]-ethane.** See Di-(methylol)-methoxy-ethane

**Bis(hydroxymethyl)-methyl-aminomethane.** See under Aminomethylpropane-diols; Vol 1,p A232-R

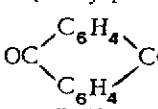
**Bis(hydroxymethyl)-methane.** See Di(methylol)-methyl-methane

**4,4-Bis(hydroxymethyl)-oxazolidone.** See 4,4-Di-(methylol)-oxazolidone

**Bis(hydroxymethyl)-peroxide.** See Di(methylol)-peroxide

**Bis(hydroxyphenyl)-anthranone and Derivatives**

*10,10-Bis(4-hydroxyphenyl)-9-anthranone*[called 10.10-Bis(4-oxy-phenyl)-anthron-(9) or 10-oxo-9.9-Bis(4-oxy-phenyl)-9.10-dihydro-anthracen in Ger],



$C(C_6H_4.OH)_2$; mw 378.40, O 12.68%; ndls(from dil alc), mp 308-309°; other props and method of prepn are given in Beil **8**, 373,(677)

*10,10-Bis(4-hydroxyphenyl)-x,x-dinitro-9-anthranone,* $(HO)_2C_{26}H_{14}O(NO_2)_2$; mw 468.40, N 5.98% grn-yel lfts, mp 236°; other props and method of prepn are given in Beil **8**,(677)

*10,10-Bis(4-hydroxyphenyl-x,x,x,x-tetranitro-9-anthranone,* $(HO)_2C_{26}H_{12}O(NO_2)_4$; mw 558.40, N 10.03%; lemon-yel ndls(from acet+MeOH), mp 278°; readily sol in alc, AcOH, chlf or acet; less sol in eth; was prepd by nitration of the dinitro deriv

*Ref*: Beil **8**,(677)

**10,10-Bis(4-hydroxyphenyl)-x,x,x,x,x,x-hexanitro-9-anthranone**[called *Hexanitrophenolanthrone* in JCS **100** I,656(1911)], $(HO)_2C_{26}H_{10}O(NO_2)_6$; mw 648.40, N 12.96%; crysts(from acet+MeOH); readily sol in alc; insol in eth or ligroin; was prepd by nitration of the tetranitro deriv(Refs 1 & 2). Its expl props were not investigated

Refs: 1)Beil **8**,(678) 2)W.W.Schwarwin et al, ZhRusFiz-KhimObshch **43**,570(1911) & JCS **100** I,655-6(1911)

**4[Bis(p-hydroxyphenyl)-methylene]-2,5-cyclo-hexadiene-1-one.** See under Aurine; Vol 1,p A508-R

**Bis(hydroxyphenyl)-propane and Derivatives**

*Bis(hydroxyphenyl)-propane,* $C_{15}H_{16}O_2$; mw 228.28, O 14.02%. Two isomers are described in the literature: $CH_3.CH_2.CH(C_6H_4.OH)_2$[called 1.1(or α.α)-Bis-(4-oxyphenyl)-propan in Ger(Ref 1)]; and $(CH_3)_2C(C_6H_4.OH)_2$ [called 2.2(or β.β)-Bis-(4-oxy-phenyl)-propan in Ger(Ref 2)]. Their props and methods of prepn are given in the Refs. $Q_c$ at 25° 1868kcal/mol & $Q_f$ 88.2kcal/mol for 2,2-Bis(4-hydroxyphenyl)-propane(Ref 3)

*Refs*: 1)Beil **6**,1011 &[977] 2)Beil **6**,1101,(493) & [978] 3)W.N.Hubbard et al, JACS **70**,3259 (1948)

*2,2-Bis(x-nitro-4-hydroxyphenyl)-propane*[called β.β-Bis-(x-nitro-4-oxy-phenyl)-propan in Ger], $(CH_3)_2C[O_2N.C_6H_3.OH]_2$; mw 318.28, N 8.80%; golden yel crysts, mp 133°; forms a dk-red Na salt; other props and method of prepn are given in Beil **6**,1012

**2,2-Bis(3,5-dinitro-4-hydroxyphenyl)-propane** [called β.β-Bis-(x,x-dinitro-4-oxy-phenyl)-propan in Ger],$(CH_3)_2C[(O_2N)_2C_6H_2.OH]_2$; mw 408.28, N 13.72%; lt-yel crysts, mp 233-4°, expl on heating to higher temps; readily sol in hot w and alkali; diffc sol in alc, benz or eth; can be prepd by nitration of the acetate of 2,2-bis(4-hydroxyphenyl)-propane(Refs 1 & 2) or by heating equimolar amts of phenol and acetone in excess $H_2SO_4$ followed by nitration (Refs 3,4 & 5)

Analogous compds have been prepd by condensing a variety of aldehydes and ketones with phenols, the parent compds forming salts which were claimed to be suitable as ignition agents (Refs 3,4 & 5)

Its *Lead Salt* of 2,2'-bis(3,5-dinitro-4-hydroxyphenyl)-propane has been patented(Ref 4) as an ingredient, in admixture with $KClO_3$, or zirconium and NS, of ignition compositions; and as being suitable for use in Electric Blasting Initiators

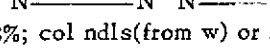
*Refs*: 1)Beil **6**,1012 2)T.Széki,CR **1904** II,1737 3)DuPont,BritP 431945(1935) & CA **30**,109(1936) 4)W.F.Filbert & W.E.Lawson,USP 2118501(1938)

& CA **32**,5630(1938) 5)Blatt,OSRD **2014**(1944)

**Bis(hydroxyphenyl)-sulfone and Derivatives**
*Bis(4-hydroxyphenyl)-sulfone*(called *Sulfonyldiphenol* in CA 5th Decennial Formula Index)[called Bis(4-oxy-phenyl)-sulfon; 4.4'-Dioxy-diphenylsulfon or 4.4'-Dioxy-sulfobenzid in Ger], $HO.C_6H_4.SO_2.C_6H_4.OH$; mw 252.29, O 25.37%; ndls(from w), mp 238-239°; forms salts; other props and methods of prepn are given in Beil **6**, 861 & [853]
*Bis(3-nitro-4-hydroxyphenyl)-sulfone*, $O_2S[O_2N.C_6H_3.OH]_2$; mw 340.27, N 8.23%; yel -wh pltlts(from alc), mp 236°; forms numerous salts; other props and methods of prepn are given in Beil **6**,865-6
*Bis(x-nitro-4-hydroxyphenyl)-sulfone*(called x-Dinitro-x-dioxy-diphenylsulfon in Ger), yel plates (from AcOH), mp 229-230°, burns without exploding; other props and method of prepn are given in Beil **6**, [858]
**Bis(3,5-dinitro-4-hydroxyphenyl)-sulfone**[called *4,4'-Sulfonyl-bis(2,6-dinitrophenol)* in CA 5th Decennial Formula Index] [called Bis(3.5-dinitro -4-oxy-phenyl)-sulfon or 3.5.3'.5'-Tetranitro-4.4' -dioxy-diphenylsulfon in Ger], $O_2S[(O_2N)_2C_6H_2.OH]_2$; mw 430.27, N 13.02%; very bitter-tasting straw yel ndls(from boiling w), mp 257-258°(Ref 4); insol in most org solvs; can be prepd by nitrating either bis(3-nitro-4-hydroxyphenyl)-sulfone or bis(4-hydroxyphenyl)-sulfone and by hydrolyzing bis(3,5-dinitro-4-chlorophenyl) -sulfone(Refs 1 & 2). It forms salts which can be used in ignition compositions(Ref 3)
*Refs*: 1)Beil **6**,867 2)F.Ullmann & J.Korselt, Ber **40**,647(1907) 3)Blatt,OSRD **2014**(1944) 4)G.Machek et al,Montsh **80**,9(1949) & CA **43**, 6994(1949)

**Bis(hydroxypropyl)-amine.** Same as Di(propylol) -amine

**N,N'-Bis(β-hydroxypropyl)-ethylenediamine.** Same as N,N'-Di(propylol)-ethylenediamine

**5,5'-Bis(1-hydroxytetrazole)** or *5,5'-Bi(1-hydroxytetrazole)* [called 1.1'-Dioxy-[di-tetrazolyl-(5.5')] in Ger],  , mw 170.10, N 65.88%; col ndls(from w) or lfts(from alc); color gradually becomes yel to brn on storage; mp expl violently on heating to 176°; sol in alc or boiling w; insol in other solvs; dissolves in concd $H_2SO_4$ with sl foaming; gives a lt brn-red color with ferric chloride; dec on heating with dil alkali; was prepd by treating the hydrazine salt of oxaldihydrazide dioxime $[C_2H_8N_6O_2+N_2H_4$, Beil **2**,560] with $NaNO_2$ in dil HCl, under cooling. This compd detonates violently on impact or friction(Refs 1 & 2). It is of lower power and brisance than PA and considered too sensitive for use as a high expl(Refs 3 & 4)
*Refs:* 1)Beil **26**,608 2)H.Wieland,Ber **42**,4205 (1909); JCS **96** I,885(1909) & CA **4**,330(1910) 3)A.H.Blatt & F.C.Whitmore,OSRD **1085**(1942),p4 4)Blatt,OSRD **2014**(1944)

**Bis(α-hydroxy-β,β,β-trichloroethyl)-peroxide** or *Bis(2,2,2-trichloro-1-hydroxyethyl)-peroxide* (called Dichloralperoxydhydrat in Ger), $Cl_3C.CH(OH).O.O.CH(OH).CCl_3$; mw 328.81, O 19.47%; lfts or pltlts(from benz or chlf), ndls+1 mol eth(from eth, dec on exposure to light, mp 122 °(dec); readily sol in alc, eth or AcOH; less sol in benz or chlf; was obtd by treating chloral ether with an ethereal soln of $H_2O_2$ or with Caro's reagent(persulfuric acid, $HO.SO_2.O.OH$) (Refs 1,2 & 3)
Minkoff(Ref 4) detd the infra-red absorption spectra of this compd and of a number of other org peroxides
*Refs*: 1)Beil **1**,623 2)A.Baeyer & V.Villiger, Ber **33**,2481(1900) & JCS **78** I,627(1900) 3)Tobolsky & Mesrobian(1954),171 4)G.J. Minkoff,PrRoySoc **224A**,184(1954) & CA **49**, 57(1955)

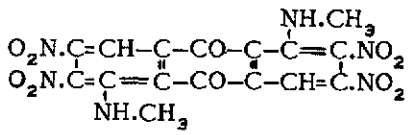
**Bisimidazoline.** See Biimidazoline

**Bis(Δ²-2-imidazolinyl).** See Biimidazoline

**Bis(methoxymethyl)-peroxide.** See Di(methoxymethyl)-peroxide

**Bis(methylamino)-anthraquinone and Derivatives**
*Bis(methylamino)-anthraquinone*, $C_{16}H_{14}N_2O_2$. Two isomers are described in the literature: *1,5-Bis(methylamino)-anthraquinone*(called Dimethyldiaminoanthraquinone by Schmidt), (Ref 2) and *1,8-Bis(methylamino)-anthraquinone* (Ref 3,p 739)(Compare with Diaminodimethyl -anthraquinone)
*Dinitro-bis(methylamino)-anthraquinone*, $C_{16}H_{12}N_4O_6$. According to Ref 3,p 737, nitration of 1,5-isomer to give *4,8-dinitro-1,5-bis(methylamino)-anthraquinone* was patented in Germany (Ger P 156759). This patent was not at our disposal

**Tetranitro-bis(methylamino)-anthraquinone,** $C_{16}H_{10}N_6O_{10}$; mw 446.29, N 18.83%. One isomer is described in the literature: *1,5-Bis-(methylamino)-tetranitro-anthraquinone,*



(positions of nitro groups are uncertain); red-violet crysts(from amyl alc + ethanol), mp220° (dec); exploded violently when heated in quantity; was prepd by nitration of 1,5-bis(methylamino)-anthraquinone with nitric acid(d 1.4) at a temp below 30°(Ref 3,p 738)
*Refs*: 1)Beil- not found 2)R.E.Schmidt,Ber **37**,70(1904) 3)R.H.Hall & D.H.Hey,JCS **1948**, 737-9 & CA **42**,8183(1948)

**Bis(methylamino)-benzene.** See under Dimethylphenylenediamine and Derivatives

**Bis(methylamino)-benzil and Derivatives**
*4,4'-Bis(methylamino)-benzil,* $C_{16}H_{16}N_2O_2$. Although not found in the literature, it may be considered as a parent compd of the following nitro deriv:
**4,4'-Bis(methylamino)-3,5,3',5'-tetranitrobenzil,** $CH_3.NH.C_6H_2(NO_2)_2.CO.CO.C_6H_2(NO_2)_2NHCH_3$; mw 448.30, N 18.75%; brn-grey powd(from nitrobenz), mp 223°; was prepd by heating 3,5,3',5'-tetranitro-4,4'-dimethoxybenzil with an alcoholic soln of methylamine. Its expl props were not detd
*Refs*: 1)Beil **14**, [98] 2)J.van Alphen,Rec **48**, 1119(1929) & CA **24**,844(1930)

**Bis(methylamino)-benzophenone and Derivatives**
*4,4'-Bis(methylamino)-benzophenone,* $C_{15}H_{16}N_2O$ is described in Beil **14**, 89
*4,4'-Bis(methylamino)-3,3'-dinitro-benzophenone,* $C_{15}H_{14}N_4O_5$ is described in Beil **14**,100
*4,4'-Bis(methylamino)-3,5,3',5'-tetranitrobenzophenone,* $[CH_3NH.C_6H_2(NO_2)_2]_2CO$; mw 420.29, N 20.00%; gold, shiny crysts(from boiling phenol), mp ca 225° (dec); diffc sol in common solvs; other props and method of prepn are given in Beil **14**,100
**4,4'-Bis(methylnitramino)-3,5,3',5'-tetranitrobenzophenone,** $[O_2N.N(CH_3).C_6H_2(NO_2)_2]_2CO$; mw 510.29, N 21.96%; lt yel crysts, mp dec ca 215°; almost insol in common solvs; sl sol in acet or AcOH; was prepd by treating 4,4'-bis-(dimethylamino)-benzophenone (Michler's Ketone) in the cold with nitric acid of sp gr 1.48 and boiling the mixt. If nitric acid of sp gr 1.53 is used, the mixt takes fire. Other props and methods of prepn are given in the Refs. Galinowski & Urbański(Ref 3) prepd the compd by treating Auramine Hydrochloride with $H_2SO_4$ + $HNO_3$ at 60-70°
*Refs*: 1)Beil **14**,100 2)P.van Romburgh,Rec **6**, 251 & 367(1887); JCS **54** II, 1079 & 1196(1888) 3)S.Galinowski & T.Urbanski, JCS **1948**,2169-70(1948) & CA **43**,2982(1949)

**Bis(methylamino)-diphenylmethane and Derivatives**
*4,4'-Bis(methylamino)-diphenylmethane,* $C_{15}H_{18}N_2$ is described in Beil **13**,239 & [111]
*Mono-,Di- and Trinitroderivatives-* not found in Beil
*4,4'-Bis(methylamino)-3,5,3',5'-tetranitrodiphenylmethane,* $CH_2[C_6H_2(NO_2)_2.NH.CH_3]_2$ mw 406.31, N 20.69%; orn crysts, mp 250°(dec); sol in boiling et acet, acet, AcOH or chlf; diffc sol in alc, petr eth or benz; other props and method of prepn are given in Beil **13**,246
**4,4'-Bis(methylnitramino)-3,5,3',5'-tetranitrodiphenylmethane,** $CH_2[C_6H_2(NO_2)_2.N(NO_2).CH_3]_2$; mw 496.31, N 22.58%; yel crysts, mp darkens at 210°, dec ca 217-220°; mod sol in warm acet; almost insol in boiling alc, eth, petr eth, chlf or $CS_2$; was prepd by treating an acetic acid soln of 4,4'-bis(dimethylamino)-diphenylmethane with nitric acid of d 1.5. When boiled with phenol, this compd gives the above 4,4'-bis(methylamino)-tetranitro deriv. When oxidized with chromic anhydride($CrO_3$) in AcOH, it is converted to 4,4'-bis(methylnitramino)-3,5,3',5'-tetranitrobenzophenone. Other props are given in Refs. Its expl props were not investigated
*Refs*: 1)Beil **13**,246 2)P.van Romburgh,Rec **7**,228(1888) & JCS **56** I,146(1889)

**Bis(methylaminomethyl)-methylamine and Derivatives**
*Bis(methylaminomethyl)-methylamine,* $HN.CH_2-N(CH_3)-CH_2.NH$; mw 117.19, N 35.85%; not found in Beil; may be considered the parent compd of its dinitramino deriv, described below:
**Bis(methylnitraminomethyl)-methylamine,** $O_2N.N(CH_3)-CH_2-N(CH_3)-CH_2.N(CH_3).NO_2$; mw 207.19, N 33.80%; nearly col crysts(from chlf), mp 64.5-65.5; when heated in a test tube, it melted and decompd; dropped on a red-hot plate, it ignited with a bright flame(Ref 2); was prepd by adding methylnitramine to an aq soln of methyl-

amine and formaldehyde cooled to 5°(Ref 3)
*Refs:* 1)Beil- not found 2)R.McGill,OSRD **787** (1942) 3)J.R.Johnson,OSRD **915**(1942),pp 2 & 30

**Bis(methylamino)-toluene and Derivatives**
*Bis(methylamino)-toluene,* $C_9H_{14}N_2$. One isomer *3,4-Bis(methylamino)-toluene,* $CH_3C_6H_3(NH.CH_3)_2$ is described in Beil **13**,153

**Bis(methylamino)-dinitrotoluene,**
$CH_3.C_6H(NO_2)_2(NH.CH_3)_2$; mw 240.22, N 23.33%. Two isomers are described in the literature:
*2,4-Bis(methylamino)-3,5-dinitrotoluene,* exists in two forms, red lfts, mp 168-170°, on crystn from acet converts to yel form, and yel ndls, mp 110°, changes to red form at 140°(Ref 1); and *3,5-Bis(methylamino)-2,4-dinitrotoluene* lt red crysts, mp 140°(Ref 2). Other props and methods of prepn are given in the Refs
*Refs:* 1)Beil **13**,142 & (42) 2)Beil **13**,165

**2,4-Bis(methylnitramino)-3,5-dinitrotoluene,**
$CH_3.C_6H(NO_2)_2[N(NO_2)\text{-}CH_3]_2$ mw 330.22, N 25.45%; crysts, mp 169°; sol in boiling alc; diffc sol in cold alc; insol in w; was prepd by nitrating 2,4-bis(methylamino)-3,5-dinitrotoluene. Its expl props were not detd
*Refs:* 1)Beil **13**,(42) 2)J.J.Blanksma,Rec **29**, 413(1910)

**2,4-Bis(methylnitrosamino)-3,5-dinitrotoluene,**
$CH_3.C_6H(NO_2)_2[N(NO).CH_3]_2$; mw 298.22, N 28.18%; almost col lfts(from alc), mp 132°, very stable compd,; partly decompd by boiling with AcOH; was prepd by treating either 2,4-bis(methylamino)-3,5-dinitrotoluene or 2-methylamino-3,5-dinitro-4-methylnitrosamino-toluene with Na nitrite. Its expl props were not detd
*Refs:* 1)Beil **13**,143 2)A.Sommer,JPraktChem **67**,560(1903) & JCS **84** I,657(1903)

**3,5-Bis(methylamino)-2,4,6-trinitrotoluene,**
$CH_3.C_6(NO_2)_3(NH.CH_3)_2$; mw 285.22,, N 24.56%; red crysts (from alc), mp 156°; was prepd by heating an alc soln of 3,5-dibromo-2,4,6-trinitrotoluene with methylamine in a closed tube
*Ref:* Beil **13**,165

**3,5-Bis(methylnitramine)-2,4,6-trinitrotoluene,**
$CH_3.C_6(NO_2)_3[N(NO_2).CH_3]_2$; mw 375.22, N 26.13%; col crysts, mp 199-200°(dec), expl when heated on a Pt foil in a flame; can be prepd by heating either 3,5-bis(methylamino)-2,4-dinitrotoluene or 3,5-bis(methylamino)-2,-4,6-trinitrotoluene with nitric acid of d 1.52
*Refs:* 1)Beil **13**,165 2)J.J.Blanksma,Rec **23**, 127(1904) & JCS **86** I,566(1904)

**Bis(1-methyl-1-ethyl-2-propynyl)-peroxide,**
See Vol 1,p A66-R

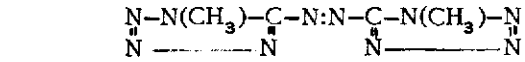
**1,3-Bis(3-methyl-4-nitro-5-pyrazolyl)-triazene,**
$\underline{HN.N:C(CH_3).C(NO_2):C.N:N.NHC:C(NO_2).C(CH_3)}:N.NH$; mw 295.23, N 42.72%; yel crysts, mp 151-2°, dec violently with evolution of gas; dissolves in dil NaOH giving an intense violet-red soln, which on acidification reppt the compd unchanged; insol in aq alk carbonates; was prepd by treating 3-methyl-4-nitro-5-amino-pyrazole in HCl at 0° with $NaNO_2$ and Na acetate for several hours. This compd forms an orn-red *Silver salt;* reacts with diazomethane to form the trimethyl deriv, a yel compd, mp 163-4° (dec); and with phenylisocyanate, PhNCO, to form a compd, golden-yel crysts,, turning maroon-red at 150°, dec at 240°.
The parent compd in alc soln was found to be fairly good indicator for titration of acids but less precise in titrating alkalies
*Refs:* 1)Beil- not found 2)C.Musante,Gazz **76**,297(1946) & CA **41**,7298(1947)

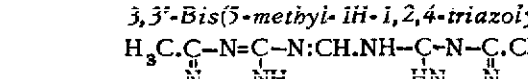
**Bis(methylphenylamino)-ethane and Derivatives**
*2-Bis[(2', 3' or 4')-methylphenylamino]-ethane or 1,2-Bis[(2', 3' or 4')-methylanilino]-ethane* [called N.N'-Di(o,m or p-)-tolyl-äthylendiamin in Ger], $H_3C,C_6H_4.NH.CH_2.CH_2.NH.C_6H_4.CH_3$; mw 240.34, N 11.66%. Three isomers are described in the literature. All form cryst salts. Other props and method of prepn are given in Beil **12**, 825,868, & 974
*1,2-Bis(4'-methyl-2',6'-dinitrophenylamino)-ethane* $H_3C(O_2N)_2C_6H_2.NH.CH_2.CH_2.NH.C_6H_2(NO_2)_2.CH_3$; mw 420.34, N 20.00%; orn lfts(from dil dioxane), mp 233°; can be prepd from 4-methyl-2,6-dinitroanisole and 1,2-diaminoethane(Ref 2). The nitration of 1,2-bis(2' or 3'-methylphenylamine)-ethane to give tetranitro derivs of undetermined structure had been described earlier in the literature(Ref 1)
*Refs:* 1)Beil **12**,826 & 868 2)W.L.C.Veer,Rec **57**,1006(1938)

**1,2-Bis[N-(4'-methyl-2',6'-dinitrophenyl)-nitramino]-ethane,**
$H_3C.(NO_2)_2.C_6H_2.N(NO_2).CH_2.CH_2.N(NO_2)\text{-}C_6H_2(NO_2)_2.CH_3$; mw 510.33, N 21.97%; crysts, mp 229-230°, expl on heating to higher temp; was prepd by nitration of either 1,2-bis(4'-methylphenylamino)-ethane(Ref 2) or 1,2-bis(4'-methyl-2',6'-dinitrophenylamino)-eth-

ane(Ref 3)
*Refs*: 1)Beil- not found 2)A.E.Schouten,Rec **56**,560(1937) 3)W.L.C.Veer,Rec **57**,1006 (1938)

**Bis(methylphenylamino)-propane and Derivatives**
*1,3-Bis[(2' or 4')-methylphenylamino]- propane or 1,3-Bis[(2' or 4')-methylanilino]- propane* [called α,γ-Di(o or p)-toluidino-propan or N,N'-Di(o or p)-tolyl-trimethylendiamin in Ger] $H_3C.C_6H_4.NH.CH_2.CH_2.CH_2.NH.C_6H_4.CH_3$; mw 254.36, N 11.01%. Two isomers are listed in Beil **12**,828, & 977
*1, 3-Bis(4'-methyl-2',6'-dinitrophenylamino)-propane*, $H_3C(O_2N)_2C_6H_2.NH.CH_2.CH_2.CH_2.NH.C_6H_2(NO_2)_2CH_3$; mw 434.36, N 19.35%; golden yel scales(from acet+ some et acet), mp 206°; was prepd by boiling in alc soln 4-methyl-2,6-dinitroanisole with 1,3-diaminopropane. This compd gives an expl nitramine deriv on nitration
*Refs*: 1)Beil- not found 2)W.L.C.Veer,Rec **57**,1006(1938)
**1,3-Bis[N-(4'-methyl-2',6'-dinitrophenyl)-nitramino]-propane**, $H_3C.(O_2N)_2C_6H_2.N(NO_2).CH_2.CH_2.CH_2.N(NO_2).C_6H_2(NO_2)_2CH_3$; mw 524.36, N 21.38%; pale yel crysts, mp 181° (decomp at a lower temp if impure); expl on heating to a higher temp; sol in dioxane; sl sol in boiling alc, chlf or benz; insol in w, eth or petr eth; was prepd by nitrating either 1,3-bis(4'-methylphenylamino)-propane or 1,3-bis(4'-methyl-2',6'-dinitrophenylamino)-propane
*Refs*: 1)Beil- not found 2)W.L.C.Veer,Rec **57**,1005-1006 & 1013(1938)

**Bis(1-methyl-1,2,3,4-tetrazolyl-5)-diazene;**
*5,5'-Azobis(1-methyl-1,2,3,4-tetrazole) or 1,1'-Dimethyl-5,5'-azotetrazole* (called Dimethyl-1,1'-azo-5,5'-tetrazol in Ger),

mw 194.17, N 72.14%; orn-yel crysts, mp 182(dec), expl sharply in contact with a flame or by friction; was prepd by shaking & warming on a steam bath methyl-5-aminitotetrazole with a dil aq soln of Ca hypochlorite. Reduction gave the *Hydrazo* deriv, cryst + $H_2O$, mp 158°(dec)
*Refs*: 1)Beil-not found 2)R.Stollé et al, JPrakt-Chem **134**,287(1932) & CA **26**,5565(1932)

**N,N'-Bis(5-methyl-s-triazol-3-yl)-formamidine or**
*3,3'-Bis(5-methyl-1H-1,2,4-triazolyl)-formamidine*,

mw 206.21, N 53.34%; wh rhombs, mp 275°; was prepd by boiling for 2 hrs, 2 mols of 3-amino-5-methyl-s-triazole with an excess of over 1 mol ethyl orthoformate, followed by cooling. This high-nitrogen compd was patented as a stabilizer for photographic emulsions. Its expl props were not investigated
*Refs*: 1)Beil- not found 2)J.D.Kendall & H.G.Suggate,USP 2,534,914(1950) & CA **45**, 2350(1951) 3)Ibid,USP 2,588,538(1952) & CA **46**,4405-6(1952)

**Bis(3-methyl-2,4,6-trinitrophenyl)-amine.**
See 2,4,6,2',4',6'-Hexanitro-3,3'-dimethyl-diphenylamine; Vol 1,p A443-R

**Bis(naphthyl)-succinamide and Derivatives**
*Bis(α- naphthyl)-succinamide*(called Bernsteinsäure-bis-α-naphthamid or N,N'-Di-α-naphthyl-succinamid in Ger), $C_{10}H_7.NH.CO.CH_2.CH_2.CO.NH.C_{10}H_7$; mw 368.42, N 7.60%; ndls(from AcOH), mp ca 285° (dec); sl sol in w or alc; diffc sol in AcOH; other props and method of prepn are given in Beil **12**,1235
*Bis(mononitro-α-naphthyl)-succinamide*, $C_{24}H_{18}N_4O_6$, not found in Beil or in CA thru 1956
*N,N'-Bis(x,x-dinitro-α-naphthyl)-succinamide*, $(O_2N)_2C_{10}H_5.NH.CO.CH_2.CH_2.CO.NH.C_{10}H_5(NO_2)_2$; mw 548.42, N 15.33%; yel ndls(from AcOH), mp ca 225°(dec); insol in w or alc; was prepd by treating the parent compd in AcOH slurry with $HNO_3$, as described in Beil **12**, 1264
**N,N'-Bis(x,x,x,x-tetranitro-α-naphthyl)-succinamide**, $(O_2N)_4C_{10}H_3.NH\ CO.CH_2.CH_2.CO.NH.C_{10}H_3(NO_2)_4$; mw 728.42, N 19.23%; microcryst yel mass, mp 256°(dec); insol in cold AcOH; was obtd on nitrating the parent compd with $HNO_3$
*Refs*: 1)Beil **12**,1265 2)H.Hübner,Ann **209**,384 (1881)

**Bis(β-nitraminoethyl)-amine.** See under Bis(β-aminoethyl)-amine

**1,2-Bis(2-nitramino-2-imidazolin-1-yl)-ethane.**
See under Aminoimidazoline and Imidazoline Substituted Derivatives; Vol 1,p A220-R

**1,2-Bis(2-nitramino-3-nitro-1-imidazolidyl)-ethane.**
See under Aminoimidazoline and Imidazoline Substituted Derivatives; Vol 1,p A220-R

**3,3-Bis(nitratomethyl)-butene-1.** Same as 3,3 -Di(nitratomethyl)-butene-1

**Bis(p-nitrobenzoyl)-furoxan.** See Di(p-nitrobenzoyl)-furoxan under Dibenzoylfuroxan

**Bis(nitrobenzoyl)-peroxide.** See Di(nitrobenzoyl) -peroxide under Dibenzoylperoxide

**2,2-Bis(3-nitro-5-methyl-4-hydroxyphenyl)-propane** or *Di(3-nitro-5-methyl-4-hydroxyphenyl)-dimethylmethane*, $(O_2N)(HO)(CH_3)C_6H_2.C(CH_3)_2C_6H_2(CH_3)(OH)(NO_2)$; mw 346.33, N 8.08%, OB to $CO_2$ -171%; yel crysts, mp 195-196°; can be prepd by condensation of o-cresole with acet(in $H_2SO_4$) followed by nitration

Its salts can be used in ignition compositions

*Refs*: 1)Beil- not found 2)DuPont,BritP 431-945(1936) & CA **30**,109(1936)

**Bis(nitrophenyl)-nitrosamine.** See Di(nitrophenyl)--nitrosamine under Diphenylamine

**1,5-Bis(p-nitrophenyl)-1H-tetrazole.** See Di(p -nitrophenyl)-1H-tetrazole under Diphenyltetrazole

**1,4-Bis(nitrosohydroxylamino)-benzene.** See under Di(hydroxylamino)-benzene

**Bis(nitrosohydroxylamino)-methane.** See under Di(hydroxylamino)-methane

**Bisnitrosoimidazoline.** See under Biimidazoline

**Bis(β-nitroxyethyl)-amine Nitrate.** See under Di(ethylol)-amine

**Bis(β-nitroxyethyl)-amine Picrate.** See under Di(ethylol)-amine

**N,N'-Bis(β-nitroxyethyl)-ethylenedinitramine.** See under 1,3-Di(β-ethylol)-ethylenediamine

**Bis(nitroxyethyl)-nitramine or DINA.** See Diethanolnitramine Dinitrate under Di(ethylol) -amine

**Bis(β-nitroxyethyl-N-nitro)-oxamide or NENO.** See under Di(ethylol)-oxamide

**Bis(β-nitroxyethyl)-oxamide.** See N,N'-di(2 -nitroxyethyl)-oxamide under Di(ethylol)-oxamide

**N,N'-Bis(nitroxymethyl)-ethylenedinitramine.** See under N,N'-Di(methylol)-ethylenediamine

**Bis(nitroxymethyl)-methylaminomethane.** See 2-Amino-2-methyl-1,3-propanediol Dinitrate under Aminomethylpropanediols in Vol 1,p A232 -R

**N,N'-Bis(β-nitroxypropyl)-nitramine.** See under N,N-Di(propylol)-amine

**Bis(penta-fluorosulfur) Peroxide,** $(SF_5)_2O_2$, col liq,fr p -95.4, bp 49.4°; it is one of the useful reagents for producing certain peroxides. Its prepn and props are described in detail by C.I.Merrill and G.H.Cady,Univ of Washington (Seattle),Tech Rept No **27**(1960)(9pp)(to Office of Naval Research)

**1,2-Bis(phenylamino)-ethane.** See Bis(anilino) -ethane

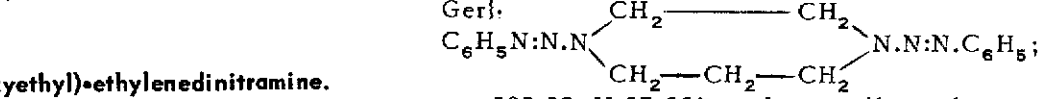
**Bis(phenylamino)-ethanol.** See Di(phenyl)-amino -N-ethanol

**1,3-Bis(phenylamino)-propane.** See Bis(anilino) -propane

**4,4'-Bis(phenylazo)-azoxybenzene.** See Bis-(benzeneazo)-azoxybenzene

**Bis(phenylazobenzene).** See Bis(benzeneazo-benzene)

**N,N'-Bis(phenylazo)-cyclo-2,3,5,7-penta-methylene-1,4-diamine** or *N,N'-Bis(phenylazo)-ethylenetrimethylenediamine* {called N.N'-Bis -benzoldiazo-[äthylen-trimethylen-diamin] in Ger}.



mw 308.38, N 27.25%; yel crysts(from alc or ligroin), mp 118°; was prepd by treating a benzenediazonium sulfate soln with a HCl soln of ethylene in 1N NaOH. Other props are given in the Refs. This compd can probably be nitrated to give expl derivs

*Refs*: 1)Beil **23**,17 2)W.Esch & W.Marckwald, Ber **33**,761(1900) & JCS **78** I,336(1900)

**Bis(phenylazo)-dihydroxy-naphthalene and Derivatives**

*Bis(phenylazo)-dihydroxy-naphthalene* (called Bis-benzolazo-dioxy-naphthalin in Ger),

$(C_6H_5.N:N)(HO)C_{10}H_4(OH)(N:N.C_6H_5)$; mw 368.38, N 15.21%. Several isomers are described in Beil **16**,200,201,(277,278) & [87]

**1,8-Bis(4-nitrophenylazo)-2,7-dihydroxy-naphthalene**[called 1.8-Bis(4-nitro-benzolazo)-2.7-dioxy-naphthalin in Ger], $(O_2N.C_6H_4.N:N)(HO)C_{10}H_4(OH)(N:N.C_6H_4.NO_2)$; mw 458.38, N 18.34%; crysts(from nitrobenz), mp dec above 300°; sol in anisole, pyridine, nitrobenz or dimethylaniline; sol in alkalies and in concd $H_2SO_4$, giving a brn-red color; sl sol in xylol, almost insol in toluene and glac AcOH; was prepd from 2,7-dihydroxy-naphthalene and 4-nitrobenzenediazonium chloride in alkaline soln. The mixt of monoazo- and bisazo- compds is separated by means of the greater solubility of the former in toluene

*Refs*: 1)Beil **16**,202 2)F.Kaufler & E. Bräuer,Ber **40**,3275(1907) & JCS **92** I,799(1907)

*Note:* Higher nitrated derivs of the parent comp were not found in Beil or in CA thru 1956

**N,N'-Bis(phenylazo)-ethylene-trimethylene-diamine.** Same as N,N'-Bis(phenylazo)-cyclo-2,3,5,7-pentamethylene-1,4-diamine

### Bis(phenylazo)-glycine and Derivatives

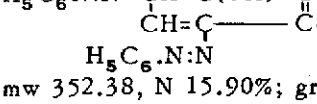
**N,N'-Bis(phenylazo)-glycine**[called *Bis(benzene-diazo)-glycocoll in* CA Ref and Bis(benzol-diazo)-glykokoll or Diphenyl-pentazdien-essig-säure in Ger], $(C_6H_5N:N)_2N.CH_2.COOH$; mw 283.28, N 24.72%; crysts mp expl 124°; was prepd from glycine(amino-acetic acid), NaOH and benzene-diazonium chloride at 0°

**N,N'-Bis(4-nitrophenylazo)-glycine,** $(O_2N.C_6H_4.N:N)_2N.CH_2.COOH$; mw 373.29, N 26.27%; yel crysts, mp expl 166-7°; was obtd as 26% of the product from the reaction of $p\text{-}O_2N.C_6H_4N_2Cl$ with 3 mols of 0.1N NaOH, together with 20% of $p\text{-}O_2N.C_6H_4.N:NNHC_6H_4.NO_2\text{-}p$

*Refs*: 1)Beil- not found 2)M.Busch et al, JPrakt-Chem **140**,117(1934) & CA **28**,5425(1934)

### Bis(phenylazo)-naphthol and Derivatives

*2,4-Bis(phenylazo)-1-naphthol* [called 2.4-Bis-benzolazo-naphthol-(1) in Ger],



mw 352.38, N 15.90%; grn-black, intensive bronze, shiny ndls(from amyl alc) or crysts (from chlf+alc), mp 190-2°; other props and methods of prepn are given in Beil **16**,161 & [254]

**2,4-Bis(4-nitrophenylazo)-5-nitro-1-naphthol,** $C_{22}H_{13}N_7O_7$, mw 487.38, N 20.12%; dk crysts (from benz or acet+w), mp 265° dec; mod sol in benz or toluene; sl sol in anisole or acet; diffc sol in alc; insol in alkalies; dissolves in in concd $H_2SO_4$ giving a green color; was prepd by treating 4-nitrobenzene<1-azo-4>-5-nitro-1-naphthol in alc soln with 4-nitro-benzene-1-diazoniumchloride. Its expl props were not investigated

*Refs*: 1)Beil **16**,162 2)F.Kaufler & E.Bräure, Ber **40**,3272(1907) & JCS **92** I, 799(1907)

**Bis(phenylazoxy)-azoxybenzene.** See Bis-(benzeneazoxy)-azoxybenzene and Derivatives

**Bis(p-phenylbenzoyl)-furoxan,** $C_{28}H_{18}N_2O_4$. Its props and methods of prepn are given in Conf ADL,"Synthesis and Testing of High Explosives", 3rd Rpt(1953),p 384 and 4th Rpt (1956),p 58

**Bis(phenyl)-ethylenediamine.** Same as Bis-(anilino)-ethane

### Bis(phenyl)-ethyleneglycol Ether and Derivatives

*Bis(phenyl)-ethyleneglycol Ether or 1,2-Di-phenoxy-ethane* (called Äthylen-glykol-di-phenyläther or α.β-Diphenoxy-äthan in Ger), $C_6H_5.O.CH_2.CH_2.O.C_6H_5$; mw 214.25, is described in Beil **6**,146 & [150]

*Bis(mononitrophenyl)-ethyleneglycol Ether or 1,2-Bis(nitrophenoxy)-ethane* [called Äthylen-glykol-bis(nitro-phenyläther) in Ger], $O_2N.C_6H_4.O.CH_2.CH_2.O.C_6H_4.NO_2$; mw 304.25, N 9.21%. Three isomers are described in Beil **6**,219,224,232 & [223]

*Bis(2,4-dinitrophenyl)-ethyleneglycol Ether or 1,2-Bis(2,4-dinitrophenoxy)-ethane*[called Äthylen-glykol-bis(2.4-dinitro-phenyläther) in Ger], $(O_2N)_2C_6H_3.O.CH_2.CH_2.O.C_6H_3(NO_2)_2$; mw 394.25, N 14.21%; lt yel crysts(from acet or phenol), mp 215.2°; readily sol in boiling acet, AcOH or phenol; insol in w, alc, eth, chlf or benz; was obtd in small quantity by Fairbourne & Toms(Ref 2) on concentrating the mother liquor from the AcOH crystn of the prod from 1-chloro-2,4-dinitrobenzene in ethylene glycol and an ethylene-glycollic soln of NaOH. Ryan & Kenny(Ref 3) prepd the compd by nitration of lower nitrated derivs of bis-(phenyl)-ethyleneglycol ether using nitrogen peroxide or $HNO_3$. Dosios & Tsatsas obtd this compd by nitration of the parent compd with fuming $HNO_3$ at -10° or by reaction of the disodium salt of ethylene glycol with an

excess of fused 1-chloro-2,4-dinitrobenzene (Ref 4). This latter reaction may result in deflagration but it proceeds smoothly if the disodium salt is added in small proportions
*Refs*: 1)Beil **6**,[243] 2)A.Fairbourne & H. Toms,JCS **119** II,2077(1921) & CA **16**,1072 (1922) 3)H.Ryan & T.Kenny,SciProcRoy-DublinSoc **17**,305(1924); JCS **126** I,505(1924) & CA **18**,1655(1924) 4)C.Dosios & T. Tsatsas,CR **180**,1276(1925) & JCS **128** I,655 (1925)

**1,2-Bis(2,4,6-trinitrophenyl)-ethyleneglycol Ether** or *1,2-Bis(2,4,6-trinitrophenoxy)-ethane*, $(O_2N)_3C_6H_2.O.CH_2.CH_2.O.C_6H_3(NO_2)_3$; mw 484.25, N 17.35%, crysts(from acet+alc), mp 197° C; mp fumes and ignites, but not violently, on being heated in an open dish; was prepd by nitration of the bis(2,4-dinitro) deriv in $H_2SO_4$ using mixed acid at 0-10°. This compd does not expl by impact. It was studied with the expectation of prepg a compd having expl props similar to trinitroanisole(qv,Vol 1, p A450ff) but without unfavorable toxic effects of the latter
*Refs*: 1)Beil- not found 2)CA- not found 3)R.C.Elderfield,OSRD **907**(1942),p 8(PB No 31085)

## Bis(phenyl)-guanidine and Derivatives

*N,N'-Bis(phenyl)-guanidine or N,N'-Diphenyl-guanidine*(called N.N'-Diphenyl-guanidin in Ger), $C_6H_5.NH.C(:NH).NH.C_6H_5$; mw 211.26, N 19.89%; ndls(from alc) or monoclinic prisms; mp 151.5°. It is described in Ref 1. Forms numerous salts and addn compds. According to Sax(Ref 2), its toxicity details are unknown
*Refs*: 1)Beil **12**,369,(236) & [216] 2)Sax (1957),p 640

**N,N'-Bis(mononitrophenyl)-guanidine**, $O_2N.C_6H_4.NH.C(:NH).NH.C_6H_4.NO_2$; mw 301.26, N 23.25%. Two isomers are described in the literature: *N,N'-Bis(3-nitrophenyl)-guanidine*, flakes, mp 196-197°(Ref 1) and *N,N'-Bis(4-nitrophenyl)-guanidine*, prisms (from alc), mp ca 222°, resets and is still solid at 295°(Refs 2 & 3). Other props and methods of prepn are given in the Refs
*Refs:* 1)Beil **12**,707 & [381] 2)Beil **12**,[393] 3)W.J.S.Naunton,TransInstRubberInd **2**,147-166 (1926); JSCI **45**,378T(1926) & CA **21**,672 (1927)

*N,N'-Bis(dinitrophenyl)-guanidine*, $(O_2N)_2.C_6H_3.NH.C(:NH).NH.C_6H_3(NO_2)_2$; not found in Beil or in CA thru 1956

**N,N'-Bis(2,4,6-trinitrophenyl)-guanidine or Hexanitrodiphenyl Guanidine**, $(O_2N)_3.C_6H_2.NH.C(:NH).NH.C_6H_2(NO_2)_3$; mw 481.26, N 26.20%; no description found; was proposed in 1923 by Olsen(Ref 2) as a booster charge; was prepd as a mixt of the hexanitro deriv and more highly nitrated derivs by nitrating diphenylguanidine with mixed nitric -sulfuric acid(Ref 3). It was reported, from a limited study of its expl props(Ref 2), to be comparable to Tetryl but sl less sensitive and about 1/3 more powerful than Tetryl(Refs 3 & 4)
*Refs*: 1)Beil- not found 2)F.Olsen,ArOrdn **3**,271(1923) & CA **17**,2051(1923) 3)D.M.Jackman & F.Olsen,USP 1547815(1925) & CA **19**, 3021(1925) 4)Blatt,OSRD **2014**(1944)

## Bis{[(phenyl-phenylamino)-ethyl]-amino}-ethane and Derivatives

*1,2-Bis{[(phenyl)-(phenylamino)-ethyl]-amino}-ethane*, $C_{30}H_{30}N_4$. Although not found in the literature it may be considered as a parent compd of its nitro derivs

*1,2-Bis-{[(2''',4'''-Dinitrophenyl)-(2'',4''-dinitrophenylamino)-ethyl]-amino}-ethane*, $C_{30}H_{26}N_{12}O_{16}$, mw 810.59, N 20.74%; brn -yel cryst powd, insol in the common solvs; was obtd by treating triethylenetetramine with 1-bromo-2,4-dinitrobenzene and Na acetate in alc soln(Ref 2,p 415)

On nitration it gives the following explosive:

**1,2-Bis{[(2''',4''',6'''-trinitrophenyl)-(2'',4'',6''-trinitrophenylnitramino)-ethyl]-amino}-ethane** or *1,10-Dinitro-1,4,7,10-tetra(2,4,6-trinitrophenyl)-1,4,7,10-tetrazadecane*,

$(O_2N)_3H_2C_6.\underset{NO_2}{N}.CH_2.CH_2.\underset{C_6H_2(NO_2)_3}{N}.CH_2.CH_2.N.CH_2.CH_2.\underset{C_6H_2(NO_2)_3}{N}.C_6H_2(NO_2)_3$; mw 1080.59, $NO_2$

N 23.33%; lt yel cryst pdr, mp dec with evoln of gas; expl when heated suddenly; was prepd by treating the above bis(dinitro-dinitro-) compd, $C_{30}H_{26}N_{12}O_{16}$, with abs nitric acid, cooled to -15°(Ref 2,p 415-16)
*Refs*: 1)Beil- not found 2)J.van Alphen,Rec **55**,415-16(1936) & CA **30**,5992-3(1936)

**α,β-Bis(α-phenyl-β-picryl-hydrazino)-ethane** [called α,β-Bis(α-phenyl-β-pikryl-hydrazino) -äthan or $N^{\alpha}.N^{\alpha'}$-Diphenyl-$N^{\beta}.N^{\beta'}$-dipikryl -äthylendihydrazin in Ger],

$[(O_2N)_3C_6H_2.NH.N(C_6H_5).CH_2-]_2$; mw 664.50, N 21.08%; brick-red crysts from et acet), mp ca 202.5° when it blackens and foams; diffc sol in boiling alc; insol in eth or benz; was prepd from picryl chloride and phenylethylene hydrazine. Its expl props were not detd

*Refs*: 1)Beil **15**,496 2)M.Hischmann,Ann **310**,161(1900) & JCS **78** I,251(1900)

### Bis(phenylthio)-dimethylbenzene and Derivatives

*Bis(phenylthio)-dimethylbenzene*, $C_{20}H_{18}S_2$. Although not found in the literature, it may be considered as a parent compd of its nitro derivs

**Bis(2,4,6-trinitrophenylthio)-dimethylbenzene or Di(picrylthiol)-xylene,**

$(CH_3)_2C_6H_2[S.C_6H_2(NO_2)_3]_2$; mw 592.48, N 14.19%. The following isomers are described in the literature: *2,4-Bis(2' 4',6'-trinitrophenylthio)-1,3-dimethylbenzene*[called 2.4-Bis(2.4.6-trinitro-phenylmercapto)-1.3-dimethyl-benzol or 2.4-Dimethyl-dithioresorcin-dipikryläther in Ger], yel crysts(from AcOH), mp 211-213°; was obtd by warming 2,4-dithio-1,3-dimethylbenzene with 2 mols of picryl chloride in alc (Refs 1 & 2,p 142). Its expl props were not detd

*4,6-Bis(2',4',6'-trinitrophenylthio)-1,3-dimethylbenzene*, orn-col crysts+1 mol $C_6H_6$ (from benz), mp 258-259.5°; sol in AcOH, et acet or benz; diffc sol in alc, eth, chlf or petr eth; was prepd by warming 4,6-dithio-1,-3-dimethylbenzene with 2 mols picrylchloride in alc(Refs 1 & 2,p 138)

*2,6-Bis(2',4',6'-trinitrophenylthio)-1,4-dimethylbenzene*, yel crysts(from et acet), mp 251-255°; sol in AcOH or et acet; sl sol in alc. It was prepd in the same manner as the other isomers (Refs 1 & 2,p 147). Its expl props were not detd

*3,5-Bis(2',4',6'-trinitrophenylthio)-1,2-dimethylbenzene*(listed in CA Coll Formula Index as *3,5-Dithio-o-xylene-dipicrate*), mp 202-203° (dec); was prepd and described in Ref 3. Its expl props were not detd

*Refs*: 1)Beil **1**,(445,446) 2)J.Pollak & B. Schladler,Montsch **39**,138,142,147(1918); JCS **114** I,497-498(1918) & CA **13**,418-419(1919) 3)J.Pollak et al,Monatsh **55**,358-78(1930) & CA **24**,4005(1930)

### Bis(phenylthio)-ethylbenzene and Derivatives

*2,4-Bis(phenylthio)-1-ethylbenzene*, $C_{20}H_{18}S_2$. Although not found in the literature, may be considered as a parent compd of nitro deriv described below

**2,4-Bis(2',4',6'-trinitrophenylthio)-1-ethylbenzene or 2,4-Di(picrylthiol)-1-ethylbenzene** [called 2.4-Bis(2.4.6-trinitro-phenylmercapto)-1-äthyl-benzol or 4-Äthyl-dithioresorcin-dipikryläther in Ger],

$C_2H_5.C_6H_3[S.C_6H_2(NO_2)_3]_2$; mw 592.48, N 14.19%; dk yel ndls+1 mol $C_6H_6$(from benz), mp 197.5-199°, becomes benz free ca 100°; readily sol in benz, AcOH & et acet; diffc sol in alc; was obtd by boiling an alc soln of 2,4-dithio-1-ethylbenzene with picryl chloride. Its expl props were not detd

*Refs*: 1)Beil **6**,(441) 2)J.Pollak,Monatsh **39**,187(1918);JCS **114** I,499(1918) & CA **13**, 419(1919)

**1,3-Bis(phenyltriazeno)-benzene or 3,3'-m-Phenylene-bis(1-phenyltriazene)** (called 1.3-Bis-phenyltriazeno-benzol in Ger), $H_5C_6.HN.N{:}N.C_6H_4N{:}N.NH.C_6H_5$; mw 316.36, N 26.57%; yel crysts(from alc), mp 161°, expl on rapid heating; dec violently in cold AcOH; was prepd by reacting 1,3-diazidobenzene and phenylmagnesiumbromide in ether. Its *Silver salt*, brown powd, expl on heating without melting

*Refs*: 1)Beil **16**, [356] 2)H.Kleinfeller, JPrChem **119**,66(1928) & CA **22**,2566(1928)

### Bis(phenyl)-urea and Derivatives

*N,N'-Bis(phenyl)-urea; 1,3-Diphenyl-urea* or *Carbanilide* (called N.N'-Diphenylharnstoff or Carbanilid in Ger), $C_6H_5.NH.CO.NH.C_6H_5$; mw 212.24, 13.20%. Its prepn and props are given in Beil **12**,352,(233) & [207]

*N,N'-Bis(mononitrophenyl)-urea; Dinitro-sym-diphenyl-urea* or *Dinitrocarbanilide*, $O_2N.C_6H_4.NH.CO.NH.C_6H_4.NO_2$; mw 302.24, N 18.54%. Three isomers are described in Beil **12**,695,706,723,(343,348,353) & [381,393]

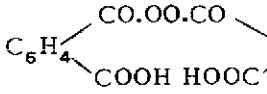
**N,N'-Bis(dinitrophenyl)-urea;** *Tetranitro-sym-diphenyl-urea* or *Tetranitro-carbanilide*, $(O_2N)_2C_6H_3.NH.CO.NH.C_6H_3(NO_2)_2$; mw 392.24, N 24.43%. Two isomers are described in the literature: *N,N'-Bis(2,4-dinitrophenyl)-urea*, yel ndls(from concd $HNO_3$), mp begins to dec ca 150°, melts ca 218 with decomposition(Ref 1); and *N,N'-Bis(3,5-dinitrophenyl)-urea*, yel ndls(from alc+w), mp 265° (Ref 2). Other props and methods of prepn are given in the Refs. Expl props of these tetranitro

compds were not detd
*Refs*: 1)Beil **12**,755,(363) & [410] 2)Beil **12**,759

**N,N'-Bis(2,4,6-trinitrophenyl)-urea; sym-Dipicryl-urea or 2,4,6,2',4',6'-Hexanitrocarbanilide** [called N.N'-Dipikryl-harnstoff; 2.4.-6.2'.4'.6'-Hexanitrocarbanilid or 2.4.6.2'.4'.6'-Hexanitro-symm-diphenylharnstoff in Ger], $(O_2N)_3.C_6H_2.NH.CO.NH.C_6H_2(NO_2)_3$; mw 482.24, 23.24%; almost col crysts(from acet+petr eth) or ndls(from acetonitrile); mp begins to dec ca 140°, dec 203-209°, expl spontaneously at 345°; readily sol in hot nitrobenz; in warm dil $H_2SO_4$, yields picric acid; in boiling ammonia, yields Trinitroaniline; can be prepd by nitration of N,N'-bis(phenyl)-urea in one, two or three stages(Refs 1 & 3) and by other methods(Refs 1 & 2)

According to Davis(Ref 3) this compd is a brisant high expl suitable for use in boosters, detonators, detonating fuses, primer caps, etc. It requires 0.19 g of MF to detonate a 0.4-g sample in the Sand Test and is sl more brisant than TNT. In the drop test, it is about the same in sensitivity to impact as Tetryl
*Refs*: 1)Beil **12**,768,(370) & [423] 2)R.I.C. Loh & W.M.DehnJACS **48**,2958(1926) & CA **21**,67(1927) 3)Davis(1943),pp 188-189

**Bis(phthalic acid)-peroxide** (called Säures Phthalperoxyd; Peroxydphthalsäure or Phthalsuperoxydsäure in Ger),



mw 330.24, O 38.76%; ndls, mp 156°(dec), expl on heating to higher temps; diffc sol in all org solvs; was prepd by treating an alkaline soln of monoperphthalic acid($CO_2H.C_6H_4.CO_3H$) with phthalic anhydride or by the direct action of $H_2O_2$ on finely divided phthalic anhydride in the presence of NaOH
*Refs*: 1)Beil **9**,804 2)A.Baeyer & V.Villiger, Ber **34**,763(1901); JCS **80** I,326(1901)

**1,5-Bis(picrylamino)-anthraquinone.** See 1,5-Bis(2,4,6-trinitroanilino)-anthraquinone under Bis(anilino)-anthraquinone

### Bis(styryl)-benzene and Derivatives

*Bis(styryl)-benzene or Distyryl-benzene*, $C_{22}H_{18}$. One isomer 1,4-Bis(styryl)-benzene is described in Beil **5**,(361)

*4,6-Dinitro-1,3-bis(styryl)-benzene*, $C_{22}H_{16}N_2O_4$, dk yel ndls(from AcOH), mp 186°; was prepd by heating 4,6-dinitroxylene with benzaldehyde in presence of piperadine
*Ref*: Beil **5**,(360)

*1,3-Bis(styryl)-2,4,6-trinitrobenzene* (called 2.4.6-Trinitro-1.3-distyryl-benzol in Ger), $C_6H_5.CH{:}CH.C_6H(NO_2)_3.CH{:}CH.C_6H_5$; mw 417.36, N 10.07%; yel ndls(from AcOH), mp 147-148°; readily sol in benz or AcOH; sl sol in acet or chlf; diffc sol in alc; was prepd from 2,4,6-trinitro-m-xylene, benzaldehyde and a little piperidine by boiling in amyl alc soln
*Refs*: 1)Beil **5**,(360) 2)W.Borsche,Ann **386**, 369(1912) & JCS **102** I,180(1912)

**1,3-Bis(4-nitrostyryl)-2,4,6-trinitrobenzene** [called 2.4.6-Trinitro-1.3-bis(4-nitro-styryl)-benzol in Ger], $O_2N.C_6H_4.CH{:}CH.C_6H(NO_2)_3.CH{:}CH.C_6H_4.NO_2$; mw 507.36, N 13.80%; brownish ndls (from acet+alc), mp 268°(dec); sol in acet; sl sol in boiling AcOH or chlf; insol in alc or benz; was prepd by heating 2,4,6-trinitro-m-xylene with p-nitrobenzaldehyde in presence of piperdine
*Refs*: 1)Beil **5**,(361) 2)W.Borsche,Ann **386**, 372(1912)
*Note*: No higher nitrated derivs of the bis (styryl)-2,4,6-trinitrobenzene were found in Beil or in CA thru 1956

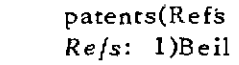
**Bis(succinyl)-peroxide;** *Disuccinyl Peroxide Bis(succinic acid)-peroxide; or Bis(3-carboxypropionyl)-peroxide* [called Bis(β-carboxy-propionyl)-peroxyd; Säures Succinperoxyd or Succinsuperoxydsäure in Ger], $HO_2C.CH_2.CH_2.CO.O.CO.CH_2.CH_2.COOH$; mw 234.16, O 54.66%; pltlts, dec slowly on long exposure to air and light; mp softens at 115°, melts with decompn ca 128°, expl on contact with open flame; sol in w, alc, acet or et acet; diffc sol in eth; sinol in benz, chlf or ligroin; was prepd by Clover & Houghton(Ref 2) from an excess of succinic anhydride added to a soln of $H_2O_2$ below 30° (Ref 1)

The aq soln of this peroxide gradually undergoes hydrolysis, forming persuccinic acid, $CO_2H.CH_2.CH_2.CO_3H$, and succinic acid. It liberates iodine rapidly from KI and oxidizes a manganous salt to permanganate. When heated with boiling xylene, it dec into $CO_2$, succinic anhydride, succinic acid, adipic acid and a gummy acidic substance

(Ref 2). Reynhart(Ref 3) found that this peroxide, when decompd at 280°, gave 58% adipic acid and 37% $CO_2$

Polarographic studies of bis(succinic acid) -peroxide were made by Willits et al(Ref 6) and by Bernard(Ref 8). Its use as a polymerization catalyst(Ref 4), particularly for tetrafluorethylene, has been the subject of several patents(Refs 5,7 & 9)

*Refs*: 1)Beil **2**,613 & [553] 2)A.M.Clover & A.C.Houghton,AmChemJ **32**,55(1904) & JCS **86** I,707-8(1904) 3)A.F.A.Reynhart,Rec **46**, 71(1927) & CA **21**,1454(1927) 4)C.S.Marvel et al,JPolymerSci **3**,433(1948) & CA **42**,8014 (1948) 5)M.M.Renfrew,USP 2534058(1950) & CA **45**,2262(1951) 6)C.O.Willits et al,Anal-Chem **24**,785(1952) & CA **46**,7934(1952) 7)S. G.Bankoff,USP 2612484(1952) & CA **47**,3618 -9(1953) 8)M.L.J.Bernard,AnnChim(Paris) **10**, 315(1955) & CA **50**,9175(1956) 9)A.E.Kroll, USP 2750350(1956) & CA **50**,13507-8(1956) 10)Sax(1957),1143

**5,5'-Bis(α- or 1,2,3,4-tetrazole) or** *5,5'-Bi(1H -1,2,3,4-tetrazole)* [called Ditetrazolyl-(5,5') in Ger],  ; mw 138.10, N 81.15%; col prisms(from w), mp 254-255°(dec); mod sol in alc or acet; sl sol in eth; insol in benz, chlf or petr eth; dec on warming in concd $H_2SO_4$; was prepd with other products by the action of $HN_3$ on cyanotetrazole, obtd from $HN_3$ and dicyan(Ref 2) and by other methods(Refs 1,3,5,6 & 8)

Bistetrazole forms many salts, some of which are expl: *Copper salt*, $CuC_2N_8$, blue ndls, expl violently on heating; *Mercury salt* expl violently; and *Silver salt*, $Ag_2C_2N_8$, yel powd, expl on heating(Refs 1,3,4 & 6) Rathsburg(Ref 5) patented the use of bistetrazole and its metal salts as components of primer or detonator compns(Ref 7)

*Refs*: 1)Beil **26**,(199) & [362] 2)E.Oliveri -Mandalà & T.Passalacqua,Gazz **43** II, 468 (1913) & CA **8**,1272(1914) 3)J.Lifschitz & W.F.Donath,Rec **37**,279(1918) & CA **13**,708 (1919) 4)E.Oliveri-Mandalà,Gazz **50** I,257 -260(1920); JCS **118** I,504(1920) & CA **14**,3412 (1920) 5)H.Rathsburg,BritP 177744(1921) & CA **16**,3399(1922);BritP 185555(1921) & CA **17**,1147(1923);GerP 401344(192 ) & JSCI **44**, B28(1925); USP 1511771(1925) & CA **19**,178 (1925); USP 1580572(1926) & CA **20**,1907 (1926) 6)G.Dedichen,AvhandlNorske-Videnskaps-AkadOslo,I,Mat-NaturvKlasse **1936**,No 5, 42pp & CA **31**,4987(1937) 7)Blatt, OSRD **2014**(1944) 8)W.Friederich,USP2710297 (1955) & CA **50**,5768(1956)

**Bis(5-tetrazole)-hydrazine or 5,5'-Hydrazo -bistetrazole** [called N,N'-Bis[tetrazolyl-(5)] -hydrazin or Bis-tetrazolinyliden-hydrazin in Ger], ; mw 168.13, N 83.32%: wh amor powd, mp 240-241° dec(Ref 4), expl on heating to higher temp; $Q_C^V$ 459.9kcal/mol (Ref 3); $Q_f$ at 25°, 135kcal/mol(Ref 3); diffc sol in boiling w; insol in org solvs; pptd by ammonia or alkalies from its soln in concd HCl to yield ppts with many metallic salts; was prepd from the Na salt of 5,5'-azotetrazole by boiling with Mg powd or better by treating with a sl excess of Zn chloride in HCl soln(Refs 1 & 2)

The alk soln of bis(5-tetrazole)-hydrazine is oxyd rapidly in the light to 5,5'-azotetrazole. The Ag, $Hg^+$ and $Hg^{++}$ salts, by boiling with dil HCl, are converted to the corresponding salts of 5,5'-azotetrazole(Refs 1 & 2)

McBride et al(Ref 4) studied the potentiometric titration of this compd & other org derivs of hydrazine with K iodate

*Refs*: 1)Beil **26**,408 2)J.Thiele,Ann **303**,66 (1898) & JCS **76** I,171(1899) 3)W.S.McEwan & M.W.Riggs,JACS **73**,4726(1951) & CA **46**, 4350(1952) 4)W.R.McBride et al,AnalChem **25**,1044(1953) & CA **47**,9863(1953)

**3,6-Bis(2H-tetrazolyl-5)-dihydro-1,2,4,5 -tetrazine** or *3,6-Di(2H-tetrazolyl-5)-dihydro -sym-tetrazine* [called 3,6-Di[tetrazolyl-(5)] -dihydro-1,2,4,5-tetrazin in Ger],  or ; mw 220.17, N 76.35%; yel crysts(dihydrate), mp(loses w on being heated in vac ca 130°), dec on heating to higher temp; insol in w, alc, eth, acet, ligroin or benz; on oxidation yields 3,6-bis(2H -tetrazolyl-5)-1,2,4,5-tetrazine; on heating with concd HCl, decomp into tetrazole, hydrazine and $CO_2$; was prepd from various derivs of tetrazole, such as 5-cyanotetrazole, by

methods given in Refs 1,2,3,& 4

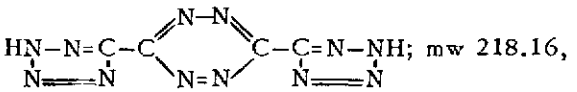
This compd forms various salts, some of which are expl: *Barium salt,* $BaC_4H_2N_{12}$, ndls, expl on heating; *Dihydrazine salt,* $2N_2H_4+C_4H_4N_{12}$, lt-yel ndls(from w), expl above 280°

*Refs*: 1)Beil **26**,(201) 2)J.Lifschitz,Ber **48**, 415-416(1915) 3)T.Curtius et al, Ber **48**, 1619, 1626,1631(1918) 4)J.Lifschitz & W.F. Donath,Rec **37**,282-284(1918) 5)F.R.Benson, ChemRevs **41**,6(1947)

**Bis[tetrazolyl-(5)]-diimide.** Same as Azotetrazole, described in Vol 1,pp A659-R to A660-L

**[$N^1$,$N^6$-Bis(α-tetrazolyl-5)]-hexazadiene.** See Vol 1,p A260-R

**3,6-Bis(2H-tetrazolyl-5)-sym(or 1,2,4,5)-tetrazine**{called 3.6-Di-[tetrazolyl-(5)]-1.2.4.5-tetrazin in Ger}

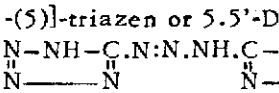


mw 218.16, N 77.05%; carmine red lfts or ndls as dihydrate (from alc), mp(loses w on being heated in vac ca 130°), expl on heating at higher temps; readily sol in w or alc; diffc sol in eth; was prepd from various derivs of tetrazole(Ref 1)

This compd forms a number of salts, some of which are expl: *Barium salt,* $BaC_4N_{12}+2H_2O$, orn-colored crysts, expl on heating; *Di-ammonium salt,* $(NH_4)_2C_4N_{12}$ red-violet crysts, mp 275°; expl ca 310° without melting according to Lifschitz & Donath(Ref 4); *Potassium salt,* $K_2C_4N_{12}$, exists in yel & violet-colored cryst forms, expl on heating; *Silver salt,* $Ag_2C_4N_{12}$, violet crysts, expl ca 150°; *Sodium salt,* $Na_2C_4H_{12}+2H_2O$, exists in yel & violet cryst forms, both modifications expl on heating

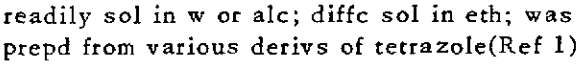
*Refs*: 1)Beil **26**(201-202) 2)J.Lifschitz,Ber **48**,415-416(1915) 3)T.Curtius et al,Ber **48**, 1619,1626,1631(1915) 4)J.Lifschitz & W.F. Donath,Rec **37**,282-284(1918) 5)F.R.Benson, ChemRevs **41**,6(1947)

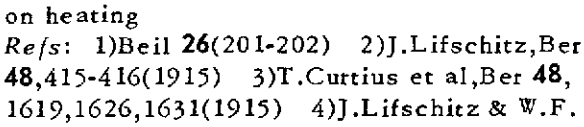
**Bis(tetrazolyl)-triazene and Derivatives**

**1,3-Bis(1H-tetrazolyl-5)-triazene or I,III-Di-(tetrazolyl-5)-triazene**{called 1.3-Di-[tetrazolyl-(5)]-triazen or 5.5'-Diazoaminotetrazol in Ger},  mw 181.13, N 85.07%; laminates(monohydrate), mp expl on heating; was prepd by treating aminoguanidine dinitrate with $NaNO_2$ and Na acetate in the presence of dil acetic acid with cooling; or by treating 5-aminotetrazole with $NaNO_2$ and Na acetate in dil acetic acid, under cooling

This compd explodes on heating or impact. It forms salts, some of which are expl: *Barium Salt,* $Ba_3(C_2N_{11})_2+8H_2O$, yel tablets (from w), expl mildly on heating; *Copper-ammonium salt,* $Cu_3(C_2N_{11})_2+2NH_3$, dk-grn pltlts, expl violently on heating, impact or friction; *Silver salt,* $Ag_2C_2HN_{11}+H_2O$,powd, expl violently on heating or on strong friction; *Sodium Salts,* several salts are known and although they are not expl, they can serve as starting materials for the prepn of expl salts

*Refs*: 1)Beil **26**,(190-191) 2)K.A.Hofmann & H.Hock,Ber **43**,1867-70(1910) & Ber **44**, 2955(1911) 3)E.Lieber & G.B.L.Smith, ChemRevs **25**,240(1939) 4)Davis(1943),448 5)F.R.Benson,ChemRevs **41**,8(1947) 6)Gilman **4**(1953),999-1000

**1,3-Bis(1H-tetrazolyl-5)-triazene,Monotriethyl Lead Salt**(called Monotriethyl-lead azoaminotetrazole by Burrows et al),  mw 474.43, N 32.46%; solid subst; was prepd by Burrows et al(Ref 2) by the action of triethyl lead acetate on the monosodium salt of 1,3-bis(1H-tetrazolyl-5)-triazene. Due to the fact that this compd can be ignited without detonation, requiring only 0.32 to 0.37 amps, its use in ignition compns for electric blasting caps was proposed by Burrows et al(Ref 2)

**1,3-Bis(1H-tetrazolyl-5)-triazene,Ditriethyl Lead Salt**(called Bistriethyl-lead azoaminotetrazole by Burrows et al),  detonates ca 180°; was prepd by the action of 2 mols triethyl lead acetate on 1 mol of the disodium salt of 1,3-bis(1H-tetrazolyl-5)-triazene. When gelatinized with nitrostarch, this compd reqd a firing current of 0.33-0.35 amps(Ref 2)

*Refs*: 1)Beil- not found 2)L.A.Burrows et al, USP 2105635(1938) & CA **32**,2357(1938)

**N,N'-Bis(thiocarbamyl)-hydrazine** (called

Hydrazin-N.N'-bis-thiocarbonsäureamid; Dithio-hydrazodicarbonamid or "Bis-thioharnstoff" in Ger), $H_2N.CS.NH.NH.CS.NH_2$; mw 150.23, N 37.30%; long prisms(from boiling w), mp softens at 215°, dec ca 221-223°; sol in boiling w; sl sol in cold w or alc; can be prepd either by dehydrazination of thiosemicarbazide or by condensation of thiosemicarbazide with thiocyanic acid (Ref 2) and by various other methods(Ref 1)

This compd is an acid and forms salts with bases. It is a combustible material which flashes when dropped on a hot plate. Due to its high nitrogen content and its compatibility with NC, the compd has been proposed for evaluation as a flash reducing agent in propellent powders(Ref 2)

*Refs*: 1)Beil **3**,196,(79) & [136] 2)L.F. Audrieth & E.S.Scott, "Compounds of High Nitrogen Content",4th Quarterly Report,Univ of Ill(Oct 1951)

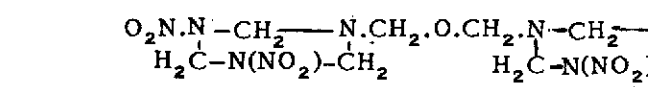
**Bistolyl.** Same as Bitolyl

**5,5'-Bis(p-tolyl)-1,1'-azotetrazole.** See 1,1'-Azo-5,5'-di(p-tolyl)-tetrazole; Vol 1,p A266-R

**Bis[5-(p-tolyl)-tetrazole-1]-diazene.** See 1,1'-Azo-5,5'-di(p-tolyl)-tetrazole; Vol 1,p A266-R

**Bis(o-toly)-triazene.** Same as Di(p-tolyl)-triazene

**Bis(1,3,5-triaza-3,5-dinitro-cyclohexylmethyl)-ether** or *Di(3,5-dinitro-1,3,5-triazacyclohexylmethyl)-ether*{called *1,1'-(oxydimethylene)-bis-[hexahydro-3,5-dinitro-s-triazine]* in CA 5th Decennial Formula Index,p 383F},



mw 396.29, N 35.35%; monoclinic crysts(from warm acet+chlf), mp begins to disintegrate at 129°; decomp extensively at 150°, forming a wh sublimate; was prepd by the action of 100% $HNO_3$, at low temp, on 1-methoxymethyl- or 1-chloromethyl-3,5-dinitro-1,3,5-triazacyclohexane and diluting the reaction mixt with eth. Its reaction with 96% $HNO_3$, acetic anhydride and acetyl nitrate was reported(Ref 2)

*Refs*: 1)Beil- not found 2)K.W.Dunning & W.J.Dunning,JCS **1950**,2928-2931 & CA **45**, 6644(1951)

**Bis(triazo)-acetic Acid, Ethyl Ester.** Same as Diazidoethylacetate, described under Ethyl Acetate

**Bis(triazo)-anthraquinone.** Same as Diazidoanthraquinone, Ditriazoanthraquinone or Anthraquinone Diazide, described under Anthraquinone and Derivatives, Vol 1,p A459-R

**Bis(triazo)-benzene.** Same as Diazidobenzene, described under Azido and Azidonitro Derivatives of Benzene

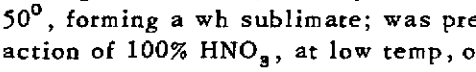
**1,2-Bistriazoethane.** Same as 1,2-Diazidoethane

**Bis(triazo)-isopropanol.** Same as Diazidoisopropanol

**Bis(β-sym or β-1,2,4-triazole) or Bi(2H-1,2,4-triazole)**{called Di[1.2.4-triazolyl]-(3.3') in Ger}, mw 136.12, N 61.75%; col lfts(from AcOH+concd HCl) or ndls(from w), effls on exposure to air; mp unchanged up to 300°, sublimes at higher temps into prismatic crysts; sol in mineral acids or alkalies; diffc sol in boiling w; insol in common org solvs; was prepd by treating cyanohydrazine with boiling formic acid(Refs 1 & 2) and by the method of Dedichen(Ref 3), who also prepd its salts. The *Silver salt* of bistetrazole can be cautiously sublimed without decomp

Wiley & Hart(Ref 4) prepd *3,4'-Bis(1,2,4-triazole)*, large wh crysts(from hot w), mp 300-302°(dec); sol in dil alk; obtd by slowly heating 3-amino-1H-1,2,4-triazole and diformylhydrazine

*Refs*: 1)Beil **26**,601 2)E.L.Rinman,Ber **30**, 1194(1897) & JCS **72** I, 444(1897) 3)G. Dedichen,AvhandlNorskeVidenskaps-AkadOslo-Mat-NaturvKlasse **1936**,No 5,42pp & CA **31**, 4986(1937) 4)R.H.Wiley & A.J.Hart,JOC **18**, 1369(1953) & CA **48**,12092(1954)

**N,N'-Bis(s-triazol-3-yl)-formamidine** or *3,3'-Bis(1H-1,2,4-triazolyl)-formamidine*,  mw 178.16, N 62.90%; wh rhombs, mp 285°; was prepd by boiling for 2 hrs 2 mols of 3-amino-s-triazole with an excess of over 1 mol of ethyl orthoformate, followed by cooling. This high-nitrogen compd was patented as a stabilizer for

photographic emulsions. Its expl props were not investigated
*Refs*: 1)Beil- not found 2)J.D.Kendall & H.G.Suggate,USP 2534914(1950) & CA **45**, 2350(1951) 3)Ibid,USP 2588538(1952) & CA **46**,4405-6(1952)

**Bis(triazo)•mesidine.** See 2-Amino-4,6-diazido-mesitylene; Vol 1,p A224-R to A225-L

**Bis(triazo)•phenanthrenequinone.** Same as Diazidophenanthrenequinone

**Bis(triazo)•propanol.** Same as Bisdiazidopropanol

**2,6•Bistriazo•4•trimethylammonium•1,4•benzoquinone.** See 2,6-Diazido-4-trimethylammonium -1,4-benzoquinone under Benzoquinoneimine and Derivatives

**Bis(triethyl)Lead Styphnate,**
$(O_2N)_3C_6H[OPb(CH_2.CH_3)_3]_2$; mw 831.87, N 5.05%; yel crysts, mp expl 204°; was prepd by Burrows et al(Ref 2) by reacting a dil alc soln of triethyl acetate with an aq soln of disodium styphnate at 60°

It was proposed for use as an ignition compn in elec blasting caps
*Refs*: 1)Beil- not found 2)L.A.Burrows et al, USP 2105635(1938) & CA **32**,2357(1938)

**Bis(2,4,6•triisopropylbenzoyl)•furoxan,**
$C_{34}H_{46}N_2O_4$. Its props and method of prepn are given in Conf ADL,"Synthesis and Testing of High Explosives", 3rd Rpt(1953),p 384 and 4th Rpt(1956),p 57

**Bis(2,4,6•trimethylbenzoyl)•furoxan,**
$C_{22}H_{22}N_2O_4$. Its props and method of prepn and its **Bis(3,5•dinitro•2,4,6•trimethylbenzoyl) •furoxan Derivative,** $C_{22}H_{18}N_6O_{12}$, are described in Conf ADL, "Synthesis and Testing of High Explosives", 3rd Rpt(1953),pp 376 & 378

**Bis(2,4,6•trimethylpyridino)•diazido•copper.** Same as Di(trimethylpyridino)-diazido-copper

**1,2•Bis(2',4',6'•trinitroanilino)•ethane.** See under Bis(anilino)-ethane

**1,3•Bis(2',4',6'•trinitroanilino)•propane.** See under Bis(anilino)-propane

**4,4'•Bis(2,4,6•trinitrobenzeneazo)•azoxy• benzene.** See under Bis(benzeneazo)-azoxybenzene

**1,2•Bis(trinitroethylamino)•benzene.** See under Di(ethylamino)-benzene

**1,4•Bis[N(2',2',2'•trinitroethyl)•carboxamide] •piperazine,**
$(O_2N)_3C.CH_2-NH.CO-N(CH_2.CH_2)_2N-CO.-NH.CH_2.CO(NO_2)_3$; mw 498.29, N 28.12; called *N,N'-Bis(2,2,2-trinitroethyl)-1,4-piperazine Dicarboxamide* and described in conf USRubber Co Summary Report,Feb 1947,p 2

**N,N'•Bis(2,2,2•trinitroethyl)•ethylenediamine.** See under Di(ethyl)-ethylenediamine

**N,N'•Bis(2,2,2•trinitroethyl)•ethyleneurea.** See under Di(ethyl)-ethyleneurea

**N,N'•Bis(2,2,2•trinitroethyl)•hydroxylamine.** See under Di(ethyl)-ethylenehydroxylamine

**Bis(2,2,2•trinitroethyl)•nitramine,** abbreviated as *BTNEN* and designated as *HOX*. Same as Di(trinitroethyl)-nitramine, listed under Diethylamine

**N,N'•Bis(2,2,2•trinitroethyl)•piperazinedi• carboxamide.** See under N,N'-Di(ethyl)-piperazinedicarboxamide

**Bis(2,2,2•trinitroethyl)•urea,** abbreviated as *BTNEU*. Same as Di(trinitroethyl)-urea, listed under Diethylurea

**Bis(1,1,1•trinitro•isobutyl)•urea,**
$C_2H_5.\underset{C(NO_2)_3}{C}H.NH.CO.NH.\underset{C(NO_2)_3}{C}H.C_2H_5$; mw 442.26, N 25.34%; an expl briefly described in conf USRubber Co "Quarterly Progress Rept No 14,Nord 10129,Feb 1,1951-May 1,1951,p 6

**1,2•Bis(2',4',6'•trinitronitranilino)•ethane.** See under Bis(anilino)-ethane

**1,3•Bis(2',4',6'•trinitro•N•nitranilino)•propane.** See under Bis(anilino)-propane

**N,N'•Bis(1,1,1•trinitro•2•octyl)•adipamide,**
$C_6H_{13}.\underset{C(NO_2)_3}{C}H.NH.CO(CH_2)_4.CO.NH.\underset{C(NO_2)_3}{C}H.C_6H_{13}$;

mw 638.59, N 17.55%; described in conf US Rubber Co Quarterly Progress Rept No 15, Nord 10129(May-Aug1951),p 7

**Bis(5,5,5-trinitro-2-pentanone)-cyanohydrazone.** See under Di(2-pentanone)-cyanohydrazone

**N,N'-Bis(2,4,6'-trinitrophenylamino)-ethane.** See under Bis(anilino)-ethane

**Bis(2,4,6-trinitrophenyl)-(α-amino-δ-guanidino-valerianic acid).** See Dipicrylarginine

**1,3-Bis(2',4',6'-trinitrophenylamino)-propane.** See under Bis(anilino)-propane

**4,4'-Bis(2,4,6-trinitrophenylazo)-azoxybenzene.** See under Bis(benzeneazo)-azoxybenzene

**Bis-N-(2',4',6'-trinitrophenyl)-1,2-dinitramino-ethane.** See under Bis(anilino)-ethane

**N,N'-Bis(2,4,6-trinitrophenyl)-ethylenediamine.** Same as 1,2-Bis(2',4',6'-trinitroanilino)-ethane described under Bis(anilino)-ethane

**N,N'-Bis(2,4,6-trinitrophenyl)-ethylene-di-nitramine.** Same as Bitetryl, described under Bis(anilino)-ethane

**1,2-Bis(2,4,6-trinitrophenyl)-ethyleneglycol Ether.** See under Bis(phenyl)-ethyleneglycol Ether

**N,N'-Bis(2,4,6-trinitrophenyl)-guanidine.** See under Bis(phenyl)-guanidine

**N,N'-Bis(2,4,6-trinitrophenyl-nitramino)-ethane.** See under Bis(anilino)-ethane

**1,3-Bis(2',4',6'-trinitrophenyl-nitramino)-propane.** See under Bis(anilino)-propane

**Bismuth**, Bi, at wt 209.00, reddish-wh metal, mp 271°, bp 1436-1440°, d 9.78 at 20°, d(molten state) 10.07 at 271°, mean sp heat(0-270°) 0.03cal/g, $Q_{vapzn}$ 42.7kcal/mol, thermal conductivity 0.018cal/sec/sq cm/°C/cm; oxidizes in moist air at RT; unites directly with halogens & sulfur; $H_2SO_4$ converts it to Bi sulfate, $HNO_3$ reacts with Bi evolving N oxides. Nicholson & Reedy(Ref 4) reported the details in which violent explns can occur when metallic Bi is heated with concd $HClO_4$. This fact had been observed previously by Fichter & Jenny(Ref 1). Sax(Ref 10) discusses the toxic nature and hazard of Bi and its salts. Vanino & Menzel(Ref 1a) obtained, on reduction of basic Bi nitrate with hydrogen, a black powdery material which oxidized spontaneously on contact with air, even at RT. They called it *pyrophorous bismuth*.

Bismuth, as a metal, has been known since the Middle Ages. It is found in ores as native metal, as the sulfide, as oxide, as carbonate, and as a minor constituent in lead, copper and tin ores. The occurrence of bismuth in the crust of the earth has been estimated to be of the same order as silver & tungsten. The recovery of bismuth from various ores and by various processes is discussed by Kirk & Othmer(Ref 6)

*Uses*. Bismuth forms a number of alloys (principally low-melting alloys), inorg compds, org salts and coordination complexes. Bismuth and some of its compds have been used in medicine and for making pharmaceutical products. Spaeth & Williams(Ref 9) patented a stable, gasless ignition or delay compn for use in elec blasting caps, consisting of bismuth 40-75, Se 25-60 and $KClO_3$ 0.5-50% (all as 200-mesh powds). In 1943, Hart(Ref 5a) made a systematic study of inorganic exothermic reactions in which the products would be gasless and the compns might be suitable as gasless powds for delay elements of fuzes. The possibility of using Bi with oxidizers, such as $Ag_2O$, $Ag_2CrO_4$, $BaO_2$, $PbCrO_4$, $Cu_2O$ & $BaCrO_4$, was considered based on the calcd heats of reactions involved, expressed as kilo calories per equivalent wt. However, many other metals were superior to Bi in this respect, and Bi is not known to be used in any US std delay compns for fuzes. DeMent(Ref 10) patented the use of powdered Bi in smoke-producing compns. Coenders(Ref 8) prepd a pyrophoric body by sintering and compacting a powd metal or alloy of a low-bp metal, such as Hg,Zn,Mg,As,Sb or Bi, with powd Ce or Ce alloy so as to produce surface alloying (See also Bismuth Alloys)

*Refs*: 1)F.Fichter & E.Jenny,Helv **6**,225(1923) & CA **17**,1599(1923) 1a)L.Vanino & A.Menzel, ZAnorgChem **149**,18-20(1925) & CA **20**,684 (1926) 2)Gmelin,Syst Nr **19**,(1927),p 13ff 3)Mellor **9**(1929),p 587ff 4)D.G.Nicholson & J.H.Reedy,TransIllStateAcadSci **27**,78(1934); CA **29**,3517(1935) & JACS **57**,817-18(1935)

5)Thorpe 1(1937),694 5a)D.Hart,PATR **1239** (1943) 6)Kirk & Othmer **2**(1948),526-30 7)Partington(1950),872ff 8)A.Coenders,GerP 811335(1951) & CA **47**,7428(1953) 9)C.P. Spaeth & C.P.Williams, USP 2607672(1952) & CA **47**,4084(1953) 10)Sax(1957),366-67 10a)J.DeMent,USP 2995526(1961),p 7

**Bismuth Alloys.** Bismuth is a component of a number of low-melting alloys. Kirk & Othmer (Ref 1) have listed eutectic alloys melting below 200° and a few non-eutectic alloys that are used extensively in industry

Some common alloys include: *Wood's metal* (mp 71°), contg Bi 4,Pb 2, Sn 1 & Cd 1 part; *Rose's metal*(mp 93.8) contg Bi 2, Pb 1 & Sn 1 part; and *Lipowitz' alloy*(mp 60-5), contg Bi 15, Pb 8, Sn 4 & Cd 3 parts. Alloys of Bi melting sl above 100° are used in automatic sprinkling systems; less fusible alloys are used as safety plugs in boilers(Ref 2). Bi alloys also have important applications in industry for castings, other miscellaneous uses, and in certain types of ammunition(Ref 1)

*Bismuth-Manganese Alloy*, developed at the Naval Ordnance Laboratory, White Oak,Md, is a suitable substitute for permanent magnets: Alnico or the expensive Pt-Co alloy. The Bi -Mn alloy can be used in various electronic devices(Ref 3). The Bi-Mn alloy known as "Bismanol", prepd by powder metallurgy techniques, is claimed to possess a coercive force of 3000 oersteds(Ref 5)

*Bismuth-Sodium Solutions*. G.P.Smith et al (Ref 4) detd the compn limits of reactions of air with solns of Na and Bi or Hg in the temp range 600-800°. For Na-Bi, the reaction was accompanied by flame or a weak expln at high temp and high Na concn. No reaction occurred at mole fraction of Na<0.45

*Refs*: 1)Kirk & Othmer **2**(1948),p 531 2)Partington(1950),p 873 3)Anon, Common Defense Bulletin No **143**(Sept 1952),Washington,DC 4)G.P.Smith et al,JACS **77**,4533 (1955 & CA **49**,15393(1955) 5)Cond Chem-Dict(1961), 152-3

**Bismuth Azide.** See Bismuth Triazide, Vol 1, pA525-L

**Bismuth Azidodithiocarbonate.** See Vol 1,p A636-R

**Bismuth Compounds.** Bismuth forms a number of inorg compds, org salts and coordination complexes. Bi halides are formed by the action of halogens on the metal. The only well -defined oxide of Bi is *Bismuth Trioxide*, $Bi_2O_3$, rhmb yel crysts, mp 820°. It is used to make some kinds of optical glass. It was also proposed for use in some smoke-producing compns(Ref 7). Higher oxides of Bi are ppted as reddish-brn powds on adding oxidg agents to alkaline suspensions of $Bi_2O_3$. According to Weingarten(Ref 8), $Bi_2O_3$ has been used by the British in some delay compns, such as: $Bi_2O_3$ 35, PbO 55 & Si 10%

The most important Bi salt is *Bismuth Nitrate*, obtd as delq crysts, $Bi(NO_3)_3.5H_2O$, by evapg a soln of the metal, oxide or basic carbonate in warm dil $HNO_3$. The soln, on pouring into a large vol of w, deposits *Basic Bismuth Nitrate*, $Bi(OH)_2NO_3$, used in medicine and formerly as a cosmetic and for the prepn of other Bi compds. Anhyd $Bi(NO_3)_3$ cannot be obtd by heating the cryst salt, as decompn occurs, but by drying in a vac over $P_2O_5$ for a year. Ozols (Ref 5) prepd *Bismuthyl Nitrates*, $[(BiO)NO_3.H_2O]$, by slow diffusion of w into $Bi(NO_3)_3$ & $HNO_3$

The toxicity and hazard of Bi compds is discussed in detail by Sax(Ref 6)

*Refs*: 1)GmelinSystNr **19**(1927),106-13 & 126-9 2)Mellor **9**(1929),643-59 & 705-11 3)Kirk & Othmer **2**(1948),p 533-40 4)Partington(1950),p 873-77 5)J.Ozols,Latvijas-PSRZinatnuAkadVestis **1950**,No 4,87-93 & CA **48**,487(1954) 6)Sax(1957),pp 367-72 7)J.DeMent,USP 2995526(1961),p 7 8)G. Weingarten,PicArsn;private communication (1961)

**Bismuth Triazide.** See Vol I,p A525-L

**Bisoflex 102.** Brit designation for tri-ethyleneglycol dicaprylate, a solvent used in cast proplnts

*Ref*: H.A.Aaronson,Dover,NJ;private communication (1960)

**Bisulfate, Sodium(Niter Cake).** A chemical in the form of col to lt straw yel globules or granules contg a min of 30% $H_2SO_4$. It is used as a flux in dissolving minerals and in pickling baths as a substitute for $H_2SO_4$. Detailed requirements of particle size and other props for the material used by the US Army, Navy & Air Force are given in Military Specification

MIL-S-16917A, Amendment 2,Feb 1956. Large quantities of this material were formerly obtd as a by-product in the manuf of nitric acid from Chilean saltpeter(sodium nitrate): $NaNO_3 + H_2SO_4 = HNO_3 + NaHSO_4$

**Bitartrate(Acid Tartrate) of Potassium or Potassium Hydrogen Tartrate**(Weinstein in Ger; Bitartrate de potassium in Fr), $KHC_4H_4O_6$, mw 188.18, col rhb crysts, d 1.956; sol in w & sl sol in alc. Can be obtained from *argol*(see Vol 1,p A480) or by synthetic methods(Refs 1 & 2). Tavernier (Ref 5) detd some thermodynamic props of K bitartrate. Crude bitartrate, packed in bags called *sachets antilueurs* in French, has been used as a flash-reducing compd in propellants(Ref 3)

*Refs*: 1)Beil **3**,494,(173) & [318-19] 2)Gmelin, Syst Nr 22,Kalium(1938),957,1162 & 1222 3)Davis(1943),325-6 4)Kirk & Othmer **13** (1954),648,652 & 655 5)P.Tavernier,MP **38**, 293,294,297 & 331(1956)

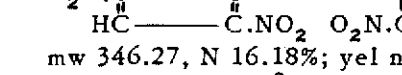
**Bitetryl.** See 1,2-Bis(2',4',6'-trinitro-nitraniline) -ethane under Bis(anilino)-ethane and Derivatives

## Bithiophene and Derivatives

*Bithiophene or Bithienyl*[called Dithienyl-(2.2' or 3.3') or $\alpha.\alpha$. or $\beta.\beta$j)-Dithienyl in Ger], $C_8H_6S_2$, mw 166.27. Two isomers are described in Beil **19**, 32,33 & [26]

*Dinitro-bithiophene*, $C_8H_4N_2O_4S_2$, not found in Beil or in CA thru 1956

**3,5,3',5'-Tetranitro-2,2'-bithiophene**[called 3,3',5,5'-Tetranitro-2,2'-bithienyl in Ref 2 ]



mw 346.27, N 16.18%; yel ndls(from AcOH), mp softens at 181°, melts at 188-190°; upon sublimation in vacuo at 200-210° and 3mm Hg, the compd melted at 194.5-196°; was prepd by heating 3,5-dinitro-2-chlorothiophene with Cu at 210-215° for 20 min(Ref 2). The UV absorption spectra were detd by Jean & Nord(Ref 3). Its expl props were not investigated

*Refs*: 1)Beil- not found 2)G.N.Jean & F.F. Nord,JOC **20**,1368(1955) & CA **50**,9377(1956) 3)G.N.Jean & F.F.Nord,JOC **20**,1377(1955)

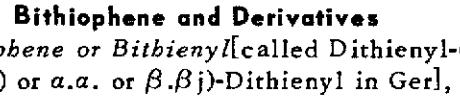
## Bitolyl and Derivatives

*Bitolyl or Dimethylbiphenyl*(called Dimethyl -diphenyl or Ditolyl in Ger), $CH_3.C_6H_4.C_6H_4.CH_3$, mw 182.25, H 7.74%. Several isomers of both sym and asym Bitolyl are described in Beil **5**,608-611,(286) & [512 -514]

**Dinitro-bitolyl or Dinitro-dimethylbiphenyl**, $CH_3.C_6H_3(NO_2).C_6H_3(NO_2).CH_3$; mw 272.25, N 10.29%. The *4,4'- 5,5'- & 6,6'-Dinitro-2,2' -bitolyls* (Ref 1); *4,4'- & 6,6'-Dinitro-3,3' -bitolyls*(Ref 2) and *2,2'- 2,3'-(?) & 3,3'-Dinitro-4,4'-bitolyls*(Ref 3) are described in the literature

*Refs*: 1)Beil **5**,609 & [512] 2)Beil **5**,610,& [513] 3)Beil **5**,610,611 & [514]

**Tetranitro-bitolyl**, $CH_3.C_6H_2(NO_2)_2.C_6H_2(NO_2)_2.CH_3$; mw 362.25, N 15.47%. Only *4,6,4',6'-tetranitro -3,3'-bitolyl* is described in the literature: lt -yel crysts(from AcOH), mp 234°; was prepd by nitrating 3,3'-bitolyl with mixed acids(Ref 2). Theilacker & Baxmann(Ref 3) prepd the compd from 3,5-dinitro-o-chlorotoluene, heated at 205-15°, by adding "Natur Cu-C" (?) followed by heating and extracting the product with benz. They obtd pale-yel crysts(from acet) melting at 198° and observed, prior to purification of the compd, a remarkable color play(brown→ green→ red → yellow) depending on the pH, indicating that traces of a compd,



were formed although it was not isolated. Its expl props were not detd

Theilacker & Baxmann(Ref 3,p 131) also attempted to prepare *5,6,5',6'-tetranitro-2,2' -bitolyl* by heating 3,4-dinitro-o-chlorotoluene with active Cu at 200°, but they were unsuccessful

*Refs*: 1)Beil- not found 2)L.H.Bock et al, JACS **52**,2058(1930) & CA **24**,3004-5(1930) 3)W.Theilacker & F.Baxmann,Ann **581**,126,131 (1953) & CA **48**,12115(1954)

**2,4,6,2',4',6'-Hexanitro-3,3'-bitolyl or 2,4,6,-2',4',6'-Hexanitro-3,3'-dimethylbiphenyl**, $CH_3.C_6H(NO_2)_3.C_6H(NO_2)_3.CH_3$; mw 452.25, N 18.58%; lt yel crysts(from AcOH), mp 240.1°; very sol in acet; sol in warm benz, toluene or AcOH; practically insol in alc or eth; was prepd by condensation of 2,4,6-trinitro-3-bromotoluene, in nitrobenz as a solvent, by means of Cu heated at a temp not over 183°. Its expl props were not investigated

*Refs*: 1)Beil- not found 2)L.H.Bock et al, JACS **52**,2056(1930) & CA **24**,3004-5(1930)

**Bitumen.** Naturally occurring, solid or semi-solid, hydrocarbons including asphalt, mineral pitch, petroleum and naphtha. The ASTM designates them as the fraction of hydrocarbons which are sol in $CS_2$. They are rich in C and H and burn with a sooty flame

Some bitumens have been used in coml expls and pyrotechnic compns as a coating for those ingredients which are either too hygroscopic or too sensitive to impact or friction to be used uncoated. Izzo(Ref 5) lists the following Ital pyro compns: a)Bitumen 10, hexachloroethane 50 Zn powd 30 & $KNO_3$ 10% b)Bitumen 10, hexachloroethane 45, Zn powd 25, $KNO_3$ 15 & ZnO 5%

See also under Asphalt, Vol 1,p A496-R

*Refs*: 1)Davis(1943),p 35 2)Hackh's(1944), p 132 4)Kirk & Othmer **2**(1948),164 and **13** (1954),618 & 643 5)Izzo,Pirotechnia(1950), 234

**Bituminite.** A brand of nongelatinous permissible explosives manufd by Hercules Powder Co, Wilmington,Del

*Ref*: Bebie(1943),p 33

**Biurea** {called Hydrazin-N.N'-dicarbonsäure -diamid; Hydrazodicarbonamid; Hydrazo -formamid; and Kohlensäure-amid-[carbaminyl -hydrazid] in Ger}, $H_2N.CO.NH.NH.CO.NH_2$; mw 118.10, N 47.44%; crysts(from w), mp 246-266°; other props and various methods of prepn are given in the literature(Refs 1 & 2)

It is compatible with NC, and the film prepd from NC and biurea gave the following stability(Ref 3): *90°C Vac Stab Test*, 2.99 cc/5 g/40 hrs; *120° Heat Test*, not acid in 300+ hrs, no red fumes in 300+ hrs and no expln in 300+ hrs

*Refs*: 1)Beil **3**,116-7,(56) & [95] 2)Inorg-Synth **4**(1953),p 26-28 3)Picatinny Arsenal data(1955)

### Biuret and Derivatives

*Biuret, Allophanamide; Allophanic Acidamide; Carbamylurea or Dicarbamylamine* (called Kohlensäure-amid-ureid, Allophansäureamid, Ureido-formamid, Ammoniakdicarbonsäure -diamid or Biuret in Ger), $H_2N.CO.NH.CO.NH_2$; mw 103.08, N 40.77%; ndls+1 mol $H_2O$(from w), loses part of its w of crystn on exposure to light; or anhyd lfts(from alc), picks up moisture on exposure to humidity and more rapidly when also exposed to light; mp becomes anhyd ca 110°, dec ca 190°; forms numerous salts, some of which are unstable; other props and methods of prepn are given in Ref 1

Rochlin et al(Ref 2) detd the basicity constants of biuret and of a number of other org nitrogen compds

*Refs*: 1)Beil **3**,70,(33) &[60] 2)P.Rochlin et al,JACS **76**,1453(1954) & CA **49**,3950(1955)

**1-Nitrobiuret**, $O_2N.NH.CO.NH.CO.NH_2$; mw 148.08, N 37.84%; wh tablets (from warm w), mp dec ca 165°, briskly foaming or exploding; according to Davis & Blanchard(Ref 2), the very pure compd dec at 233°; $Q^P_C$ 228 kcal/mol; readily sol in warm w, alc or methanol; diffc sol in cold alc or w; decompd by boiling w into $CO_2$, $N_2O$ and urea; can be prepd by nitrating biuret in cold mixed $HNO_3$-$H_2SO_4$

It forms salts, some of which are expl, for example, *Silver salt*, $AgC_2H_3N_4O_4$, wh ndls (from w by pptn with alc), expl on heating(Refs 1 & 2)

*Refs*: 1)Beil **3**,126 & [100] 2)T.L.Davis & K.C.Blanchard,JACS **51**,1803(1929) 3)S.Helf, I.Minsky & B.Guide,PATR **1841**(1951)(conf, not used as a source of info)

**1,5-Dinitrobiuret**, $O_2N.NH.CO.NH.CO.NH.NO_2$; mw 193.08, N 36.28%; wh ndls(from MeOH), mp expl ca 124°; $Q^P_C$ 203 kcal/mol; very sol in w with a strong acid reaction; dec in boiling w; sol in alc, MeOH, acet or eth; insol in chlf, ligroin or benz; can be prepd by adding, in small portions, mononitrobiuret to well cooled 100% $HNO_3$ and evaporating the soln in darkness, in vacuo, over $H_2SO_4$

It forms salts, some of which are expl, for example, *Potassium salt*, $K_2C_2HN_5O_6$, col plates(from lukewarm w), expl on heating

*Refs*: 1)Beil **3**,126 2)J.Thiele & E.Uhlfelder, Ann **303**, 95-99(1898) 3)S.Helf, I.Minsky & B.Guide,PATR **1841**(1951)(Conf, not used as a source of info)

**Bivinyl.** Same as Butadiene

### Bixylyl and Derivatives

*Bixylyl; Dixylyl or Tetramethyl-biphenyl* (called Tetramethyl-diphenyl in Ger), $(CH_3)_2C_6H_3.C_6H_3(CH_3)_2$; mw 210.30, H 8.63%. The sym isomers 2,4,2',4'-Tetramethyl-; 2,5,-2',5'-Tetramethyl-; 2,6,2',6'-Tetramethyl-(Ref 2); and 3,4,3',4'-Tetramethyl-biphenyl are described in the literature

*Refs*: 1)Beil **5**,620,(292,293) & [522] 2)J.Guy,

JChimPhys **46**,469(1949) & CA **44**,4298(1950)
*Dinitro-bixylyl or Dinitro-(tetramethyl-biphenyl)*, $C_{16}H_{14}N_4O_8$, mw 390.30, N 14.36%. Two forms of the isomer *x,x,x,x-Tetranitro-3,4,3',4'-(tetramethyl-biphenyl)* are described in the literature: a)prismatic ndls(from dil acet), mp 208-210°; and b)thin transparent ndls(from dil acet), mp 267-8°. Both forms were obtd when finely powd nitrotetramethyldiphenyl was gradually added to fuming $HNO_3$ and the soln poured into w to ppt the product. The expl props of the tetranitro-derivs were not investigated
*Refs*: 1)Beil **5**,(193) 2)A.W.Crossley & C. Herbert,JCS **99** I,724-5(1911)
*Note*: Higher nitrated derivs of bixylyl were not found in Beil or in CA thru 1956

**Bjorkmann Explosives.** C.G.Bjorkmann of Stockholn invented in 1880 two expls compns: a)$KNO_3$ 20, $KClO_3$ 20, "Cellulosa"(nitrated peas) 10, pea flour 10, sawdust 10 & "Nitroline"(nitrated mixt of stearin and sugar) 30%; and b)(product of nitration of 3ps glycerin and 1p glucose) 60, $MnO_2$ 18, K ferrocyanide 10, $Sb_2S_3$ 2 & pine sawdust or coal dust 10%
*Ref*: Daniel(1902),pp 72-3

**BKI.** A cast double-base propellant developed at ABL. Its compn & props are described in Conf "Propellant Manual", SPIA/M2(1959), Unit No 574

**BKZ.** A cast double-base propellant developed at ABL. Its compn and props are described in Conf "Propellant Manual", SPIA/M2(1959), Unit No 504

**BLA.** A cast double-base propellant developed at ABL. Its compn & props are described in Conf "Propellant Manual", SPIA/M2(1959), Unit No 505

**Black Diamond & Black Diamond Nu-Gel.** A brand of nongelatinous US permissible explosives manufd by Illinois Powder Manufacturing Co, St Louis, Mo
*Ref*: Bebie(1943),p 33

**Black Dynamite.** A mixt of powd coke and sand, impregnated with 45% by wt of NG
*Refs*: 1)Daniel(1902),p 583 2)Clift & Fedoroff, Vol 4(1946),p 10

**Black Liquor.** A by-product of paper manuf, contg tar in addn to a small amt of aromatic hydrocarbons and phenolic compds. It was considered impracticable to use this tar, or any fraction thereof, as a source of raw materials for expls
*Ref:* E.J. Hoffman,Paper **23**,No 19,11-13(1919) & CA **13**,515-6(1919)

**Black Match.** A slow-burning device used to ignite black powder, or other expl train, and pyrotechnics. It can be made conveniently by twisting a few strands of cotton twine together, dipping the cord into a paste of meal powd and drying while the cord is stretched on a frame. When black match is enclosed in a paper tube, it burns almost instantaneously and is then known as *quickmatch*. Black match may be ignited by a flame, whereas black powder on a flat surface is often difficult to ignite
*Ref*: Davis(1943), pp 4-5 & 67

## BLACK POWDER OR GUNPOWDER

(Schwarzpulver in Ger, Poudre noire in Fr, Polvere nera in Ital, Pólvora negra in Sp, Chornyi Porokh in Rus and Yuenyaku or Kokoshoku-yaku in Jap)

Black powder, the oldest explosive and propellant known, consists of a mechanical mixt of saltpeter, charcoal and sulfur in proportions varying with the purpose. Here, saltpeter is the oxygen producer, while charcoal is the combustible material. The object of sulfur is to make the powder readily inflammable and to form, on burning, K or Na sulfide (by reaction with K or Na nitrate) so as to prevent part of the $CO_2$ from forming K or Na carbonate, which would, of course, mean a reduction in the amt of gas evolved. Sulfur also imparts the neeessary tenacity and density to the powder mass(Ref 34,p 191)
*Historical* (Refs 1,2,3,5,7,8,16,22 & 27). The exact date of the discovery of BkPdr is unknown. Some historians, such as Diego Ufano, attribute its discovery to the Chinese(in the 1st century before Christ), others to the Hindus and still others consider it of Arabian origin. It is very probable, however, that mixts similar to BkPdr were used very early by the Chinese(and perhaps by the Arabs) in the manuf of fireworks, rocket-type arrows or incendiary compns, but it was not used as a propellant in firearms, as there is no proof

that these were invented before the 13th century. According to Claudius, the Romans were familiar with fireworks in the 4th century, AD and it was proved historically (Ref 16,p 32) that as early as the 7th century, the Greeks had a secret mixt which possessed props similar to those of present BkPdr. The famous Greek Fire of Kalinikos contained combustible material mixed with a substance closely resembling saltpeter in its props and through its use many naval victories were won by the Greeks against the Arabs, Turks and Russians. The secret of the compn was well guarded for about 5 centuries after its invention, but the Turks finally obtained the formula and used the Greek Fire against the Christians at the time of the 5th Crusade(1217). During the 6th Crusade(1249), the army of Saint Louis was assailed in Egypt with incendiaries thrown from ballistae, with fire tubes and with hand grenades of glass and metal, which scattered upon bursting(Ref 16,p 33). Marcus Graecus, in about 800 AD, described in detail the compn of the Greek Fire used in his time. It contained sulfur and saltpeter mixed with pitch and other combustibles. He also gives a compn of a BkPdr consisting of saltpeter, charcoal(willow or grapevine) and sulfur. Marcus Graecus' work was quoted by an Arabian physician, Mesue, living in the 9th century. Western Europe was in complete ignorance of such compns. It was sometime before 1249 that Roger Bacon, a monk living in England(1214-1292), described a mixt resembling the present BkPdr and, as far as is known, this was the first publication on BkPdr to appear in Western Europe. However, there was nothing in his writings to suggest that he contemplated the use of BkPdr for propelling missiles or as an explosive

The invention of BkPdr did not revolutionize the technique of warfare in Western Europe because there were no firearms. This situation lasted until about the beginning of the 14th century when Berthold Schwarz, a German monk living in Freiburg, described a device (an iron tube) for throwing stones a considerable distance, using BkPdr as a propelling medium. It is not certain whether this "firearm" was the invention of Schwarz, or if he only improved the already existing crude device. Although some historians, especially German, attribute to Schwarz, not only the invention of firearms, but also the invention of BkPdr, there is no proof for such a statement

Accdg to Col Hime(Ref 2), the cannon was invented in 1313 by an "unknown" German monk and was introduced in 1314. It was used in the same year at the battle of Bannockburn (Ref 8,p 1)(See also under Cannon)

It may be mentioned that the manuf of firearms and of BkPdr in Russia began about 1389(Ref 15,p 255)

Notwithstanding the advantages of firearms (compared with the bow and arrow), it was not until the end of the 15th century that they became prevalent in open warfare. By the beginning of the 16th century the compn of BkPdr was well stabilized, becoming very close to the formula used in modern times, namely, saltpeter ca 75, charcoal 12.5-15 and sulfur 10-12%. Although practically no changes have been made in the compn since that time, many improvements have been introduced which resulted in the prepn of more homogeneous mixts and in powders with better ballistic props. The ballistics of firearms were also improved through mechanical design of the weapons

Until about the 17th century cannon balls were solid pieces of either stone or iron(first introduced ca 1391) and BkPdr was used only for propelling these balls. When hollow cast iron balls, provided with an opening and filled with BkPdr, were introduced, the powder began to function also as an explosive(bursting charge). After loading a hollow ball with BkPdr, a time fuse(resembling the present Bickford fuse) was inserted through the opening in the ball. Then the gun was loaded through the mouth with a propelling charge of BkPdr and after inserting the ball, the propelling charge was ignited through a hole near the breech of the gun. The burning gases from the decompn of the BkPdr ejected the ball and ignited the time fuse. After reaching the target, the fuse ignited the charge in the ball which resulted in expln and bursting of the ball into small pieces

Another great improvement in firearms was the introduction in the middle of the 19th century of rifled barrels and then later of breech-loading. The first large-scale use of rifled firearms was during the Crimean War (1855-6) by the French, British and Italians against the Russians, who still used smooth -bore firearms at that time

As the power, brisance and velocity of

detonation of BkPdr are low, firearms using it were neither powerful nor of long range

The ancient compns were in powder form (from which the name "powder" is derived) and they burned with extreme rapidity. To make them slower burning, the Germans(according to some historians), as far back as the middle of the 15th century, introduced grained BkPdr. According to other sources it was in the Spanish Kingdom of Aragon that the first grained BkPdr was produced. At first the grains were irregular in shape and size, which lead to very non-uniform rate of burning. Gradually, it was learned that to obtain the best ballistics, the size and shape of the grain should be uniform. Napoleon was known to have used roughly cubical grains 8mm thick in the smaller field guns and grains about twice as thick in the larger guns. Later solid prismatic hexagonal grains of various sizes were introduced and in 1860 an American, Gen Rodman, developed (in an attempt to make BkPdr progressive-burning) perforated *cake powders* which consisted of large, solid, cylindrical grains(blocks) of nearly the same diam as the bore of the cannon, contg a hole about ¼" in diam along the axis of the cylinder. One grain was required for each firing. This powder was sometimes called "Mammoth". For larger cannon(such as 10 & 12-inch guns), the blocks (prisms) were made in sections(discs) which were joined by means of bands of paper glued around the joint. When these single -perforated prisms were lighted, the area of the outer surfaces decreased as the burning advanced but the area of the inner surfaces increased and a high rate of gas production was maintained. The Russians, Prussians and the British soon adopted Rodman's idea for their artillery. The perforated prisms were manufd not only in large sizes,as advocated by Rodman, but also in small sizes, and such powders, especially when used in rifled guns, gave higher velocities and greater ranges than had been possible previously

In 1862-1864, Doremus, in France, introduced powders prpd by compressing the grains. The conglomerate thus formed retained the granular structure but was slower burning than grains in the loose form. This powder was used in small and medium caliber guns and proved to be satisfactory

The last two improvements in BkPdr were made in the 70's and 80's of the 19th century just before BkPdr ceased to be a war lord, the position it had occupied for nearly six centuries(from the 1st quarter of the 14th to the last quarter of the 19th century). These improvements included: a)the use of multiple perforations in the prismatic grain by means of which the burning surface was made to increase as the burning progressed, resulting in acceleration of the rate of gas production, and b)the use of a slower burning formulation called *Brown Powder* or *Cocoa Powder* (also called *Chocolate Powder*), introduced by the Germans in 1882(see below under Black Powder Modifications)

It is interesting to note that the first BkPdr factory established on the Amer continent was in Mexico at the time of Hernán Cortez(16th century)(Ref 19). In the US, the first powders were manufd at Milton, Mass as early as 1675 and one year later were reported as being equal in quality to that of the best British powders

In 1857, the only major change which has been made in the compn of BkPdr was introduced in the US by Lammot duPont, who substituted the more abundant and cheaper sodium nitrate for the more costly potassium nitrate

The following table gives the approximate compns of BkPdr from ancient times to the end of the 19th century:

| | K Nitrate | Charcoal | Sulfur |
|---|---|---|---|
| China(before Christ) | 72.6 | 19.0 | 8.4 |
| Marcus Graecus(8th Cent) | 67 | 22 | 11 |
| Roger Bacon(ca 1252) | 37.5 | 31.25 | 31.25 |
| Arderne Formula(ca 1350) | 66.6 | 22.2 | 11.2 |
| Arabia(16th Cent) | 74 | 15 | 11 |
| Brussels Formula (Belgium)(1560) | 75.0 | 15.62 | 9.38 |
| British Govt Formula(1635) | 75.0 | 12.5 | 12.5 |
| Swedish(1697) | 73.0 | 17.0 | 10.0 |
| American Colonies(1775) | 75.2 | 13.5 | 11.3 |
| British Watson Formula (England)(1781) | 75.0 | 15.0 | 10.0 |
| Military Powders in European States (19th Cent) | 71-77 | 12.5-15 | 9-12.5 |
| Blasting Powders in Europe (19th Cent) | 62-73.5 | 12-19.4 | 14-20 |
| Sporting Powders in Europe (19th Cent) | 75-80 | 12-17 | 8-10 |
| Powder in United States (19th Cent) | 75 | 15 | 10 |

All of these improvements could not remove two props of BkPdr which render it not very desirable for use as a military propellant- low ballistic potential and production on firing of enormous amts of smoke, which quickly make the location of artillery obvious to the enemy. Its low power, brisance and velocity of detonation make it too weak for use as a bursting chge for any but cast-iron shell

With the invention, about the middle of the 19th century, of NG and NC, it became possible to produce propellants practically smokeless and of high ballistic potential. The first "smokeless" proplts(such as Austrian and British, developed betw 1864 & 1883), were not colloided. Being porous, they burned very fast and often caused gun barrels to burst. When the way was found to prep proplns as non-porous grains- by gelatinizing NC, either with alcohol [see B Poudre (invented in 1884 by P.Vieille) in this volume] or with a liq expl, such as NG see Ballistite(invented in 1888 by A.Nobel), in this volume, the use of BkPdr and of Cocoa Powder as a military proplnt was discontinued

With the discovery in the 1880's that PA (previously known for many years as an external medicine) is a very powerful and brisant expl, combined with the introduction by Turpin of new HE shells(which were/essentially the same as shells currently in use), the need of BkPdr as a bursting chge was completely eliminated. In later years, other HE's were invented, such as Explosive D (Ammonium Picrate), TNT, Tetryl, PETN, RDX, etc

Although BkPdrs are no longer used as military proplnts or as bursting charges in shells or bombs, they are still used as proplnts in some sporting weapons. They are also used as blasting expls and for some other purposes (see below under Properties of Black Powders)

The use in Europe of BkPdr as a mining expl probably began in Saxony as early as 1613 and then in Hungary ca 1627. It was used in England since ca 1670, slightly later in Sweden, and in the American Colonies since ca 1712(Simsbury, Conn)

With the growth of the steel and coal industries in the first half of the 19th century, the use of BkPdr as a blasting expl increased tremendously until the production in the US in 1860 was ca 25 million lbs per year. Production reached an all time high of 277 million lbs in 1917 but has gradually declined since that time; production in 1947 was ca 36 million lbs and in 1958 it dropped to ca 6 million lbs, of which 1% was used for blasting(Ref 33). In contrast to the figures on BkPdr, the production of dynamite in the US(mostly NG compns), used mainly in blasting operations, is currently ca 1 billion lbs annually

**Black Powders Containing Potassium Nitrate.** The compn of most current military BkPdrs is betw the following limits: K nitrate 74-78, charcoal 12-16 & sulfur 10-12.5%. Compns of many sporting and blasting powders are betw the same limits. There are, however, some exceptions, such as some Belgian blasting powders, which formerly consisted of $KNO_3$ 70-73.5, charcoal 12.5-14 & sulfur 14-16% and a Russian blasting powder: $KNO_3$ 66.6, charcoal 16.7 & sulfur 16.7%. One of the Russian sporting powders contained $KNO_3$ 80, charcoal 12 & sulfur 8%

*Preparation* (Refs 4, 16, 18 & 28). In earlier days, BkPdrs were prepd by grinding the ingredients by hand in mortars. This was superseded by the socalled *Stamp Mill*, such as is briefly described in Refs 16,18 & 28

Modern methods of prepn consist essentially of the following operations:

a) *Grinding, Mixing and Incorporating*. Charcoal(such as obtd by charring alder, willow or poplar trees) is broken up by *Wheel Mills* and then pulverized after adding the required amt of sulfur (high grade, commercial product), in a *Ball Mill*. In this operation sulfur is worked into the cellular openings of the charcoal. The dampened material is mixed with K nitrate (previously finely ground) and the moisture content adjusted to ca 4%. About 300 lbs of this mixt are placed in a *Wheel Mill*(such as described in Ref 11,p 46; Ref 18,p 69 or Ref 28,p 87) where the mass is processed during 3-6hrs. This operation is called *Incorporation or Milling*. The resulting material is called "mill cake", "clinker" or "wheel cake". It is broken into small pieces and sent to the press

b) *Pressing* is done in hydraulic presses where the material is subjected to a pressure of ca 6,000 psi. As the operation is dangerous, it is usually conducted by remote control. The cakes are broken up with wooden tools and transported to the *Corning Mill*

c) *Corning or Granulation* consists of cracking up the cake into grains of desired sizes by means of a series of adjustable rolls having corrugated surfaces. The granulated material is then passed through a series of mechanically-shaken screens where the particles of different sizes separate and the dust is removed. The particles are classified according to the size of the screen and transferred to the *Finishing House*. The coarse material is passed through the rolls a second time and rescreened. The Corning Mill Dust is collected for use in fuses or in pyrotechnics. The Corning operation is the most dangerous of all the manufg operations and must be conducted by remote control

d) *Finishing or Polishing* is accomplished by tumbling, for as long as 8 hrs, the granulated material in a wooden drum, rotating on its axis. This operation may be combined with drying which can be accomplished by a stream of hot air. If a glazed powder is desired, a small amt of fine graphite is added to the contents of the drum after the moisture has been reduced to a certain point but before the powder is too dry. The moisture content of the finished powder is ca 1%

*Note*: Final drying may be conducted by placing the powder on trays covered with canvas in the dry house

e) *Grading* of powder consists of rescreening and separating into different grain sizes. The word "grade" applied to BkPdr refers to grain size, not the quality

f) *Blending* consists of mixing various grades of powder to obtain a desired rate of burning or other props

Two processes for manufg BkPdr with modern production equipment have been developed and tested on a laboratory scale by Propellex Chemical Division of Chromalloy Corp. Their final rept(Ref 35a) on the project describes the two processes(one with and the other without the use of $CS_2$), and also briefly discusses a number of other methods suggested by M.Baer and K.Kite of PicArsn

*Properties:* BkPdr is one of the weakest expls and belongs to the class of "low expls" or "propellants". It contains sufficient oxygen for combustion to CO and nearly sufficient for combn to $CO_2$. The outstanding characteristic of BkPdr is that it can be exploded(or rather deflagrated) by ignition, yet it is very insensitive to impact, properties which are rarely encountered together

*Note:* The opinion is held by some that the powder does not explode but merely deflagrates with the evoln of gases and it is these gases which finally explode

The main disadvantages of BkPdr are: weakness, production of large amt of smoke and the corrosive action on metals of some of the products of its combustion. Alone, it is corrosive in the presence of moisture but not when dry

BkPdr is the slowest acting of all the common expls. When used for blasting operations it has a shearing and heaving action which tends to break the material into large, firm fragments or masses. This action derives from a relatively slow development of gas pressure, which is sustained. In order to obtain the best results, it must be closely confined. BkPdr is unsuitable, however, for gassy and dusty coal mines because it produces a hot durable flame. Because of its high sensitivity to friction, heat, spark and flame, danger of manuf and inability to perform in many types of hard -rock shooting, it has been replaced by other blasting expls(Ref 33)

BkPdrs contg approx: $KNO_3$ 74-75, charcoal 12.5-16 & sulfur 10-12.5%(including the compn $KNO_3$ 74.0, charcoal 15.6 & sulfur 10.4%, described in Ref 31) may be considered to possess(approximately) the following props(Refs 11,16,20,28,31 & 34):

a)*Brisance*- by Kast formula B= $1.4 \times 10^6$ vs $86 \times 10^6$ for TNT(Ref 11,p 95) by Sand Test- 8g sand crushed by 0.40g BkPdr, vs 48g for TNT(Ref 31); 6.3 to 9.0g sand crushed(Ref 36)

b)*Calorimetric Value*- ca 720cal/g(Ref 34)

c)*Compatibility*- in the dry state it does not attack any of the common metals; attacks all of them, except stainless steel, when moisture is present(as low as 0.2%)(Ref 31)

d)*Density*- 1.7 to 1.89 depending on compn and compression(Ref 28,p 87; Ref 31 and Ref 34, p 191

e)*Equation of Combustion*:

Sukharevskii & Pershakov(Ref 9) give the following equation:

$74KNO_3 + 16C_6H_2O(\text{Charcoal}) + 32S = 56CO_2 + 3CH_4 + 2H_2S + 4H_2 + 35N_2 + 19K_2CO_3 + 7K_2SO_4 + 2K_2S + 8K_2S_2O_3 + 2KCNS + (NH_4)_2CO_3 + 14CO + C + 3S$

Stettbacher(Ref 11,p 108) gives for powder contg $KNO_3$ 74.9, C 13.3 & S 11.8:

$2KNO_3 + 3C + S = K_2S + 3CO_2 + N_2$

Bofors Manual(Ref 34,p 190) gives the following equation:
$20KNO_3 + 32C + 8S = 5K_2CO_3 + K_2SO_4 + K_2S_2O_3 + 3K_2S + 2S + 11CO_2 + 16CO + 10N_2$
of which about 43% are gases and ca 57% solid residues

In TM 9-1910(Ref 28,p 86) the following equation for autocombustion of BkPdr is given:
$74KNO_3 + 96C + 30S + 16H_2 = 35N_2 + 14CO + 3CH_4 + 2H_2S + 4H_2 + 19K_2CO_3 + 7K_2SO_4 + 8K_2S_2O_3 + 2K_2S + 2KSCN + (NH_4)_2CO_3 + C + S + 56\ CO_2$

See also Ref 28a(discussion on ignition and combustion reactions of BkPdr) and Ref 28d(description of experimental investigation of the laws of combustion of BkPdr at atmospheric pressure and below)

f)*Explosion or Ignition Temperature:* 510° (0.1sec; no cap used); 490° (1sec in cap); 427°(ignites in 5sec); 356° (10sec)(Ref 31): 359°(12sec)(Ref 26a,p 1393); 457° (ignites in 5sec)(Ref 36)

g)*Flame Sensitivity*- ignites very readily(Ref 20,p 37 & Ref 28,p 86); Escales(Ref 1,p 394) gives for prismatic pdr 5.4 to 9.0 sec and for small grain pdr 3.6 to 4.5sec

h)*Friction Sensitivity* by Pendulum Test- affected with steel shoe and unaffected with fiber shoe(Ref 31); no expln with steel shoe (Ref 36)

i)*Heat of Combustion*, $Q_c^v$ ca 1425cal/g(Ref 9)

j)*Heat of Explosion*, $Q_e^v$ 665 to 690cal/g(Ref 9); 693cal/g(Ref 36)

k)*Hygroscopicity* gains 1.91% at 25° & 90% RH(Ref 31)

l)*Ignitability*, flame of a match or of a miner's squib as well as electric spark ignites it(Ref 36)

m) *Impact Sensitivity:* PicArsnApp, 2kg wt 16" (vs 14" for TNT)(Ref 31); Bofors Detn, 2kg wt ca 70 cm(Ref 34,p 191); B of M, 2kg wt 49cm for $KNO_3$ BkPdr and 66cm for $NaNO_3$ BkPdr(Ref 36)

Deck(Ref 6) gives 32" for BkPdr dust when detd by PicArsnApp with 2kg wt

n)*Initiation* and thermal decomposition of BkPdr is discussed by Blackwood & Bowden (Ref 28a)

o)*International Heat Test* at 75° - 0.31% loss in 48 hrs(Ref 31)

p)*Maximum Temperature of Explosion*- 2380° vs 2800° for TNT(Ref 11,p 95); ca 2400°(Ref 34,p 19)

q)*Power*, by Trauzl Test- 30cc expansion produced by 10g sample vs 300cc for TNT (Ref 34,p 191); 10% of TNT(Ref 31); by Ballistic Mortar 50% TNT(Ref 31); by Ballistic Pendulum 42.5% of TNT for pdr contg $KNO_3$ 75.06, charcoal 13.68, S 10.76 & moisture 0.50%(Ref 36)

r)*Rate of Burning* depends on compn, density and grain size. The rate increases on increasing the percentage of oxidizer(such as K or Na nitrate), within certain limits. The rate decreases when the percentage of fuel(charcoal, coal, brown coal, etc) is increased. With increase in the amt of sulfur, the rate increases to a certain extent, although sulfur acts mainly as a fuel and only to a small extent as an oxidizer(because it forms $K_2S$). The rate decreases with an increase in grain size and sl decreases with increase in density. When confined, increase in gas pressure causes increase in burning rate(Ref 20,pp 37-8 & Ref 28b,pp 86-7). W.O.Snelling & W. C.Cope, USBurMines Tech Paper **6**,Washington,DC(1912), give the rate of burning of fuse pdr as influenced by temp, pressure, moisture and granulation. For instance, an 80-mesh pdr burns at atm press and ord temp at the rate of 82.3sec/m(25.1 sec/ft) vs 76.3sec/m(23.2sec/ft) for 40-60-mesh pdr. A cotton covered safety fuse burns at atm press and 18° at the rate of 82.3sec/m(25.6sec/ft) vs 49.8(15.2) at 15psi and 34.4(10.5) at 30psi(p 15). Moisture & high temps cause a decrease in burning rate. Safety fuses mfd by the DuPont Co burn either 90 or 120sec/yd(Ref 28,p 89). Some fast-burning fuse pdrs burn ca 30sec/yd, whereas some modified slow-burning pdrs, such as those contg aldol-α-naphthylamine and aldol-β-naphthylamine, burn at the rate of 250-300sec/yd[H. H.Holmes & W.E.Lawson,USP 2414465(1947) & CA **41**,2578(1947)]. Escales(Ref 1,p 396) gave for a rifle BkPdr at 1atm press 0.80cm/sec & at 500atm 6cm/sec; the corresponding values for a brown prismatic pdr were 0.90 & 4cm/sec. US Army Purchase Description X-PA-PD-623 gives "static burning time" requirements for fuze pdrs when tested directly in fuzes. For instance, for fuzes M54, M55A3, M77 or M84 the *average burning time* shall be 18.0 to 23.0sec and the *"minimum average burning time"* 36.0sec. The corresponding values for M65A1 fuze are 9.0 to 13.0sec & 18.0sec. Tests for "rates of burning" of black blasting pdr and for pellet pdr are described by C.E.Munroe & J.E.Tiffany, Bur-

Mines Bull **346**, "Physical Testing of Explosives", Govt PrtgOff,Washington,DC(1923). Combustion of BkPdr at atm and lower pressures was studied by A.Douillet,MP **37**, 167-96(1955)

s)*Sensitivity to Electrostatic Discharge* (Joules) >12.5 for unconfined and 0.8 for confined sample(Ref 31)

t)*Sensitivity to Flame.* See Flame Sensitivity

u)*Sensitivity to Sparks and Incandescent Particles*- very sensitive(Ref 28,p 88)

v)*Specific Energy*(f) 2310 vs 8080 for TNT (Ref 11)

w)*Specific Heat* ca 0.2cal/g at RT(Ref 36)

x)*Vacuum Stability*- 0.5ml/40hrs/100° and 0.9ml/40 hrs/120° (Ref 31); 0.86ml/40 hrs/120° for black meal powder and 0.75 for meal pdr contg 2% stearic acid(Ref 36)

y)*Velocity of Detonation*- ca 400m/sec at d 1.6-1.7 vs 6825 for pressed and 6640 for cast TNT at d 1.56(Ref 31); 400m/sec at 1.7(Ref 34,p 191)

z)*Volume of Combustion Gases* at 0° & 760mm 271-280 l/kg vs 690-730 for TNT; ca 280 l/kg (Ref 11,p 95 & Ref 34,p 191)

z ) *Uses:* Sporting propInts, blasting and demolition expls, time fuses, primers, igniters(of smokeless propInts), time rings(in fuzes), delay & relay elements, petards, pyrotechnics, base chge for shrapnel shells(now seldom used), bursting chge for blank, saluting & practice cartridges & shells, flash reducer (in some smokeless propInts), squib charges, Navy donuts for catapult charges, smoke-puff chges, chemical ammo as well as in Rocket, JATO and missile boosters and sustainers (Ref 28b,p 86; Ref 31 & Ref 34)

**Black Powders, Containing Potassium Nitrate, Used in the United States of America.** Requirements for the US Armed Forces are covered by the Specification JAN-P-223A for the powder alone; JAN-P-156 for potassium nitrate; JAN-C-178A(1) for charcoal(usually obtd by burning peeled willow, alder or certain hardwoods); JAN-S-487 for sulfur and JAN-G-155(1) for graphite. The compn is the same for all grades: K nitrate 74.0, charcoal 15.6 & sulfur 10.4%, but tolerances vary slightly (up to ± 1.0%). The ash content for all grades is 0.80%(max), moisture 0.70% for all grades except A-1, for which the max is 0.50%, and the density is 1.72 to 1.77. No foreign matter such as gritty or fibrous particles shall be present

For a description of various grades of US military BkPdrs and their uses, see JAN-P-223A

The compns listed above may be considered as *fast-burning*, while the following compn is *slow-burning*: K nitrate 59.0, charcoal 15.6, sulfur 10.4 & Ba nitrate 15.0%. By blending fast- with slow-burning mixts in different propns, it is possible to obtain powders suitable for various types of fuzes

Another *slow-burning* mixt is the so-called *Coal Powder*. Its compn is: K nitrate 70.0±1.0, coal 14.0±1.0 & sulfur 16.0±1.0%. The US Armed Forces requirements for this powder are given in Spec X-PA-PD-623(listed as Type II Powder, Black, Slow Burning) which superseded Spec JAN-P-540. The coal used for this powder must be semibituminous and of such fineness that 100% passes through No 140 US Std sieve and not less than 45% through No 200 sieve. Other requirements for coal are: moist 0.75%(max), ash 11.0±1.5, volatile matter 18.0±1, fixed carbon 70.5±3.5 & sulfur 3.0±0.5%; no foreign matter, such as gritty or fibrous particles, shall be present. This BkPdr shall be of such fineness that 3%(max) is retained on a No 140 US Std sieve and 2%(max) retained on a No 200 sieve. Static burning time, when loaded in US Std Fuzes M54, M55A3, M77, M84 and M65A1, must be as indicated above under *Rate of Burning*(item r). No gritty or fibrous matter shall be present

A BkPdr used in US *time fuzes* for military ammo consists of K nitrate 74.0±1.0, charcoal 15.6±1.0 & sulfur 10.4±1.0% and the requirements of the US Armed Forces are covered by Spec X-PA-PD-623 (listed as Type 8, Powder, Fuze), which superseded Spec JAN-P-TRP. The ash content 0.60%(max) and granulation must be of such fineness that 3%(max) is retained on a No 140 US Std sieve and 2%(max) passes through a No 200 sieve. When loaded in US Std Fuze M54, M55A3, M77, M84 and M65A1 the static burning time of the powder must be as indicated above under *Rate of Burning*(item r); no gritty or fibrous matter shall be present

BkPdrs for blasting operns by the DuPont Co are described in Ref 27,pp 45-8. Their *Pellet Powder* may be considered as an improved form of BkPdr

**Black Powders, Containing Potassium Nitrate, Used in European Countries.** BkPdrs used in

Europe have practically the same formulations as those used in the US. As an example, the following compns of powders were used in France before WW II(Ref 12,p 280)

| | K nitrate | Charcoal | Sulfur |
|---|---|---|---|
| Poudre de Guerre (Military powder) | 75 | 12.5 | 12.5 |
| Poudre de mine forte (Strong mining expl) | 75 | 15 | 10 |
| Poudre de mine ordinaire (Ordinary mining expl) | 62 | 18 | 20 |
| Poudre de mine lente (Slow mining expl) | 40 | 30 | 30 |
| Poudre de chasse* (Sporting powder) | 78 | 12 | 10 |
| Poudre de guerre brun (Brown military powder) | 78 | 19 | 3 |

*P.Tavernier,MP **36**,232(1954) gives for black sporting powder: $KNO_3$ 75-78, charcoal 12-15 &S 9-12%

As there is no info at our disposal on current British BkPdrs, we are using here the description given in Thorpe(Ref 13a,p 584). The powders used in England were classified according to the size of grain. Some of them described below are definitely obsolete

a)*Grain Powders* were prepd by passing irregularly broken pieces of pressed cake through a series of rolls, each set of rolls causing a progressive reduction in the size of the grains. In the case of small arms powder, the grains were first reduced to pass through No 10 BritStd sieve and were then screened on a No 20 sieve to remove fines and dust. The sized grains were then polished and coated with graphite and Al powder

b)*Pebble Powders* were manufd first ca 1865. The press-cake was cut into uniformly sized cubes ranging from 5/8" to 1.5" on a side. These powders were larger than ordinary grain powders and were used in order to prevent the development of excessive pressures. They are now obsolete

c)*Perforated Cake Powder*, devised in the US by Rodman ca 1860, was made in the form of cylindrical cakes which were pierced axially with ca ¼" holes. The cakes were of the same diam as the bore of the gun in which they were used and were packed in cartridges with the holes in one cake aligned with those in the adjacent cake. These cakes were easily broken, however, in the course of transportation and were soon replaced by prismatic powder(see below)

d)*Prismatic Powder* was made in the form of hexagonal prisms, ca 1.25" wide and 1" deep, with a hole through the center 0.4" in diam. The prisms were packed to form rigid cartridges for use in guns of large caliber (See also Refs 14,15, 17,22,23,30 & 31a)

**Black Powders Containing Sodium Nitrate.** These powders, introduced in 1857 in the US by Lammot duPont, are less expensive than the $KNO_3$ compns but are more hygroscopic, much slower and slightly weaker(Ref 27)

Requirements for the US Armed Forces are covered by Specification JAN-P-362(1) for the powder itself; JAN-S-322 for sodium nitrate; JAN-C-178A(1) for charcoal; JAN-S -487 for sulfur and JAN-G-155(1) for graphite

Composition of the powder: Na nitrate 72.0 ±2.0, charcoal 16.0±2, sulfur 12.0±2.0, ash(including deterrent if used) 1.5 & moisture(max) 0.70%, density 1.72-1.84. It is glazed with graphite. There are three classes, according to granulation: a)*Class A*- 100% through No 12 sieve, 45% through No 16 and 99% retained on No 40; intended to be used for saluting chges, usually in the form of pellets b)*Class B*- 99% retained on No 16 sieve; intended for use in practice bombs c)*Class C*- 100% through a sieve opening of 9/16" and 100% retained on a sieve opening of 3/8 ; intended for use in torpedo impulse charges

Sodium nitrate BkPdrs used in mining and to some extent in demolition work are usually in the form of cylindrical *pellets* ca 2" long and ranging from 1 1/8" to 2 1/2 in diam. The pellets have a 3/8" hole in the center which facilitates rapid and uniform ignition and permits a fuse to be inserted into or through the pellet. This opening will also seat an electric squib. The pellets are wrapped in paper to form cartridges of any desired length (usually 8") and the cartridges are dipped in paraffin, or similar material, to protect the powder from moisture. Pellets are more convenient and less dangerous to handle than other forms of BkPdr(Ref 27)

Pepin Lehalleur(Ref 12,p 287) and Sancho (Ref 15,pp 285-6) give compns of some European powders contg Na nitrate, such as:

See Chart Next Page

| Composition | De Tret's Pyronome | Freiberg & Wetzlar's | Soulage Powder |
|---|---|---|---|
| Na nitrate | 71.3 | 61.7-66.7 | 50-60 |
| Charcoal | 15 | 17.4 | 12-16 |
| Sulfur | 13.5 | 11.8-17.2 | 13-6 |
| Soot | - | - | 9-18 |
| Oak Bark | - | 18.7 | - |
| Iron Sulfate | - | - | 4-5 |
| Moisture | - | 2.8 | - |

**Black Powder Modifications.**

A modification of BkPdr, known as *Brown-, Cocoa-, or Chocolate Powder* (so named because of its brownish color) was invented in Germany ca 1882. It contained K nitrate 79, brown charcoal(contg ca 2% $H_2O$) 18 & sulfur 2% and was made in the form of prisms. The brown charcoal was prepd by incompletely charring a light wood or straw and hence contained more volatiles than black charcoal. The compn of Brown Pdr was kept secret until the Russians published in 1886 the formulation of their own powder manufd at the Ochta plant, near St Petersburg. The Russian powder consisted of K nitrate 78.4, brown charcoal 19.6 (prepd from incompletely charred rye straw) and sulfur 2.0%. As the partially charred wood or straw possesses some colloidal props, it enabled the compn to flow under pressure, thus cementing the grains together, as in the case of sulfur. This made possible a reduction in the amt of sulfur or even its complete elimination, thus making the powders slow-burning. The use of Brown Pdr greatly improved the ballistics of big guns and made possible the use of larger caliber guns than could be used with BkPdr. Also, for equal muzzle velocities. Brown Pdr produced less pressures than BkPdr(Ref 13a). Brown Pdr was also used by the US Armed Forces, as late as 1898, during Spanish-American War

A modification of BkPdr which does not contain sulfur is called *sulfurless black powder*, A sample of such pdr manufd by the King Powder Co was examined at PicArsn in 1941. The pdr contained $KNO_3$ ca 70 & charcoal 30% Its d was 1.63(Ref 36)

A BkPdr used in *safety fuses* must consist of fine, uniformly grained particles free from dust. This type of powder must be of special quality and constant compn, contg, in some cases, various additives for controlling the rate of burning

Lowering of the burning rate may be achieved by one of the following methods:
a)Addn of inert bodies, such as brick dust, graphite, Ba or Pb sulfate, oxides of various metals. Fuses contg these substances do not burn very uniformly and they leave large residues
b)Addn of rosin. This method increases the time of burning from 45 sec per yard to 900 sec
c)Treatment of the grains of powder with a soln of NC(or other cellulose product). This treatment not only modifies the rate of burning but also renders the powder less hygroscopic
d)Substitution of pitch for charcoal may increase the time of burning from 45 to 180 sec/yd and even to 500 sec(method of Foster & White)
e)Introduction of triphenyl phosphate, camphor, substituted ureas, etc, suggested by F.Olsen
f)Substitution of cuprene, wholly or in part for charcoal

One of the most recent modifications of BkPdr is the so-called *Benite* developed at PicArsn by Hassmann(Ref 33a) for use in igniter compns of artillery primers or in base igniter bags for separate-loading ammo. This powder is, accdg to Huselton & Kaplowitz(Ref 35), in the form of extruded strands consisting of the ingredients of BkPdr($KNO_3$, charcoal & S) in a matrix of NC. The ratio of BkPdr ingredients to NC is 60/40

Benite can be manufd by a solv extrusion process, using essentially the same mixing, extrusion & drying facilities employed in the manuf of double and triple base cannon proplnts. Based on production engrg studies to improve the manufg process, Huselton & Kaplowitz(Ref 35) developed an acceptable spec which was practical for production use. Some requirements in the R & D Spec PA-PD-1741, such as moisture content, total volatiles, & the use of reagent gd $KNO_3$ were changed. The resulting changes are contd in the current spec, MIL-B-45451, 27 Jan 1960

Both the friction pendulum and deton hazard (solv wet) tests show that Benite reacts similarly to single base, M-18 proplnt and therefore may be considered a Class 2 expl hazard when wet. The functioning characteristics of of benite are relatively unaffected by minor changes in dimensions of the strands and formulation (Ref 35)

Details of the manufg procedure for std and modified Benite formulations are given by Huselton & Kaplowitz(Ref 35). Hassmann (Ref 33a) reported physical, chemical and sensitivity characteristics of std Benite in comparison with those of Grade A-1 BkPdr. The std Benite formulation, as given in the specs, is as follows: NC(13.15%N)40, K nitrate 44.3, sulfur 6.3 & charcoal 9.4% with EtCentr 0.5% added

Other modifications of BkPdrs are listed after Refs

*Refs*: 1)R.Escales,"Schwarzpulver und Sprengsalpeter",Veil & Co,Leipzig(1910) 2)H.W.L.Hime,"The Origin of Artillery",Longmans-Green,London(1915),28,60,95 & 149-69 3)Marshall **1**(1917),53-91 4)J.A.Marshall, "The Manufacture and Testing of Military Explosives",McGraw-Hill,NY(1920),114-17 5)Van Gelder & Schlatter(1927),3ff(History of BkPdr in the US) 6)H.S.Deck,ArmyOrd **7**,34 (1926)(Impact test value for BkPdr dust) 7)H.Desvergnes,ArmyOrd **10**,191-4(1929) (History of development of military powders) 8)Marshall**3**(1932),1-5 9)Sukharevskii & Pershakov(1932),169 10)Vennin,Burlot & Lécorché(1932),505-24 11)Stettbacher(1933), 3, 95 & 97-113 11a)I.V.Lapchenkov."Kurs DymnykhPorokhov",GoskhimTekhIzdat,Moscow (1933)(in Rus) 12)Pepin Lehalleur(1935),279 -89 13)Beyling-Drekopf(1936), 1 & 67-71 13a)Thorpe **4**(1940),458 14)N.A.Shilling,"Kurs Dymnykh Porokhov",Oboronguiz,Moscow(1940) (in Rus) 15)Sancho(1941),253-86 16)Davis (1943),28-51 17)M.M.Kostevitch,"Espoletas de Tiempo y Pólvora Negra para los Reguladores Inferior y Superior", Buenos Aires(1943) 17a)W.Hassenstein,SS **39**,1-9, 22-6 & 37-42 (1944) (The Chinese and the Discovery of Powder) 18)Anon, "Ammunition Inspection Guide", TM **9-1904**(1944),68-79 19)Pérez Ara(1945),133-48 20)All&EnExpl(1946),36-9 21)Stettbacher(1948),1,20 & 58-9 22)Vivas, Feigenspan & Ladreda **3**(1948),3-74 23)Giua, Dizionario **2**(149),162-4 24)J.Fauveau,MP **33**, 452(1951) (Evolution of propellants) 25)Kirk & Othmer **6**(1951),3-7 & 77(under Explosives) 26)H.Henkin & R.McGill,IEC **44**,1393(1952) & CA **46**,8857(1952) 27)Stettbacher(1952), 78-80 28)Blasters' Hdb(1952),45-8 & 89 28a)J.D.Blackwood & F.P.Bowden,PrRoySoc **213A**,285-306(1952) & CA **46**,10623(1952) 28b)Anon,"Military Explosives",TM **9-1910** (1955),86-91 28c)S.Bentur et al,PrRoySoc **230A**,33-46(1955) CA **49**,1520-1(1955)(Inhibition of burning of BkPdr by foreign substances) 28d)A.Douillet MP **37**,167-96(1955) 28e)W.Y.Carman,"A History of Firearms",St Martin's Press,NY(1955),1-11 & 157-62 29)Gorst(1957),156-9 30)Yaremenko & Svetlov(1957),110-12 31)Tomlinson & Sheffield,PATR **1740**,Rev 1(1958),32-6 31a)Fedoroff et al,PATR **2510**(1958),p Ger 173-R 32)Taylor & Gay(1958),18-21(Use of BkPdr in blasting) 33)Cook(1958),8 33a)H.Hassmann,PicArsn FREL,Propulsion Development Section Report No **1**(1958)(Conf) (Not used as a source of info) 33b)C.Campbell & G.Weingarten, TrFaradSoc **55** 2221-8(1959) 33c)Ibid,PicArsnMonograph **M43**(1959)(Thermoanalytical study of ignition & combustion) 34)A.B.Bofors Nobelkrut,"Manual on Powder and Explosives",Bofors,Sweden(1960),190-1 34a)J.R.Partington,"A History of Greek Fire and Gunpowder,Heffer,Cambridge,England(1960) 35)E.Huselton & S.Kaplowitz,PicArsnAmmo-Group, TR DB-TR **5-60**(1961)[Evaluation Tests and Process Studies Relating to Establishment of Substitute for Black Powder(Improvement in Manufacture of Benite Strands)] 35a)Chromalloy Corp, DAI-23-072-501-ORD(P) -43, Final Rept, July 1,1961 36)Wm.H. Rinkenbach,Allentown,Pa; private communication(1961)

**List of Modifications of Black Powder**

The following compns, which appear to represent the most interesting developments, are listed in chronological order:

A)J.P.Gray,USP 1438759(1922) & CA **17**,882 (1923)(Rosin 2-12% is added to BkPdr as retarder) B)Lignosa S.Akcyjna,FrP 641442 (1927) & CA **23**,1272(1929)(Charcoal in BkPdr is replaced by hydrocarbons such as $C_{10}H_8$ sulfo acids of $C_{10}H_8$ or phenols, nitrosulfo acids of phenols, nitrosulfo acids of phenols. Carbohydrates, such as cellulose, starch or sawdust also may be used) C)Dynamit A-G, PhrNaoúm & A.Hölz,GerP 499402(1929) & CA **24**,4160 (1930)(Powdered petroleum coke is used to replace charcoal) D)R.L.Hill,USP 1833573 (1931) & CA **26**,1125(1932)(Mixt of BkPdr with an O-carrying salt, such as AN or $NH_4ClO_4$ coated with graphite, rosin or paraffin) E)J.A.Hammond,CanP 311894(1931) & USP 1872941(1932); CA **25**,3838(1931) & **26**,6141 (1932)(A slow-burning & free-pouring expl is obtained by treating BkPdr with asphaltum dissolved in $CS_2$ & drying) F)R.L.Hill,USP

1845663(1932) & CA **26**,2320(1932)(Mixt of BkPdr with AN coated with a combustible material defficient in O, such as TNT, NC or a carbohydrate) G)R.L.Hill,USP 1845664 (1932) & CA **26**,2320(1932)(Mixt of BkPdr with a O-carrying salt, such as AN or $NH_4ClO_4$ coated with S & charcoal) H)W.A.McIntre, CanP326148(1932)& USP 1882853(1932); CA **26**,6140(1932) & **27**,846(1933)(Rate of burning of BkPdr consisting of $NaNO_3$, S & charcoal is decreased by incorporating ca 0.5% of a water-emulsifiable oil, such as sulfonated oil) I)B.A.Gillie,CanP 324731(1932) & USP 1927870(1933); CA **26**,5422(1932) & **27**,5981 (1933)(A slow-burning BkPdr suitable for fuses is obtained by incorporating ca 0.5% of high-viscosity oil, such as castor oil) J)C.W. Brooks,CanP 348641(1935) & CA **29**,3518(1935) (Addn of 0.1-0.5% of stearic acid retards the rate of burning; eg, $NaNO_3$ 72.0, S 10.0, charcoal 17.7 & stearic acid 0.3%) K)C.W.Brooks, Jr,USP 2030096(1936) & CA **30**,2388(1936) (Stability of BkPdrs contg AN is improved by incorporating 0.2% or more of a solid org basic compd such as urea of dicyandiamide) L)C.W.Brooks & C.R.Johnson,CanP 377516 (1938) & CA **33**,2339(1939)(Addn of 0.2-2% of a non-fibrous binding agent, such as starch, in prepn of BkPdr pellets) M)H.H.Holmes, CanP 384570(1939) & CA **34**,1488(1940)(Pellets of a deflagrating expl consisting of BkPdr, AN (15-45%) and at least one finely divided combustible metal, such as Al) N)J.Simon & D. Hewitt,USP 2179434(1939) & CA **34**,1488(1940) (Mixt of BkPdr with a product obtained by nitration with $HNO_3$ + $H_2SO_4$ of an incompletely charred cellulose) O)R.Healy,Astronautics No **53**, 3-10(1942) & CA **39**,5077(1945)(Various BkPdr compns used in rockets are discussed) P)D.Hart"Investigation of Use of Nitroindene Polymer in Powder for M54Time Fuze", PATR **1296**(1943). [Substitution of nitroindene polymer for charcoal, yielded longer burning fuze powders and lowered the ignition temp, while it considerably increased the sensitivity to impact. Compns of two pdrs examined at PicArsn were: a)$KNO_3$ 74.0, nitroindene polymer 15.6 & sulfur 10.4% and b)$KNO_3$ 67.8, nitroindine polymer 20.4 & sulfur 9.8%. The impact sensitivity of both pdrs was 20cm with 2kg wt, vs 75cm for BkPdr contg $KNO_3$ 74.0, charcoal 15.6 & sulfur 10.4%. Because of their high sensitivity to impact, the nitroindene polymer pdrs were not recommended for use in fuzes] Q)A.J.Clear,PicArsnChemLabRept **99983**(1943) (BkPdr substitute contg $KNO_3$ 40, Tetranitrocarbazole 30 & aluminum pdr 30% was prepd and examined at PicArsn) R)R.C.Payn et al, BritP 576107(1946) & CA **42**(1949)(A compn suitable for delay combustion trains by addn to BkPdrs of an aldehyde-amine condensation product) S)O.Matter,SwissP 244352(1946) & CA **43**,4468(1949)(A BkPdr substitute contg carbonaceous material prepd by extg coal with high-boiling org solvents, such as a coal -tar oil, followed by filtration and removal of the solvent from the filtrate by distn) T)W.H.Rinkenbach & V.C.Allison,USP 2415848 (1947) & CA **41**,2900(1947)(Slow-burning BkPdr suitable for fuses is prepd by replacing charcoal with non-cellular C obtd by decompn of sugar. For instance, the fuse contg:$KNO_3$ 74, S 10.4 & sugar C 15.6% burns about 3.3 times slower than the pdr contg charcoal) U)H.H. Holmes & W.E.Lawson,USP 2414465(1947) & CA **41**,2578(1947)(A faster-burning BkPdr suitable for fuses may be obtd by replacing charcoal by a special type of C black produced by incomplete combn of natural gas or other gaseous fuel. For inst, the compn $KNO_3$ 74, S 9.5 & C black 16.5% burns 46 sec/yd vs 75 secs for pdr contg charcoal) V)R.C.Payn et al,USP 2423427(1947) & CA **41**,6050(1947) (Slow-burning fuse pdr, such as 250-300 sec/yd, is prepd by incorporating 2 parts of a mixt of aldol-$\alpha$-naphthylamine & aldol-$\beta$-naphthylamine into BkPdr contg $KNO_3$ 75, alder charcoal 17 & S 8%) $V_1$)S.Livingston,PATR **1647**(1947)(Conf)(Development of non-hygroscopic igniter powder) W)M.de Simo,USP 2566602(1951) & CA **46**,1767(1952)(A BkPdr -type expl obtd by combining $KNO_3$ with sulfohydrocarbons and/or sulfocarbons in lieu of carbon and S. Details of prepn are given) $W_1$)S.Livingston,PATR **1802**(1951)(Conf)(A BkPdr substitute for use in artillery ammo) X)F.P.Bowden & J.D.Blackwood,BritP715827 (1954) & CA **49**,2736(1955)(Sulfur-free BkPdr is obtd by addg to $KNO_3$ + charcoal about 10-15% of an alkali metal salt of formic acid) $X_1$)Ibid,BritP 715828(1954) & CA **49**,2736 (1955)(The reaction rate of BkPdr may be increased as much as ten-fold by addg low-melting mixts of alkali metal nitrates, such as $LiNO_3$ + $NaNO_3$) Y)Ibid,BritP 715829 (1954) & CA **49**,2736(1955)(The reaction rate of BkPdr may be increased by addg small amts (eg 5%) of a metallic salt such as PbOAc,

which will react with $H_2S$ as it is liberated in early stages of burning) Z)H.Hassmann, PATR **2515**(1957)(Conf)(Eimite, a substitute for BkPdr in artillery primers)

**Black Powder, Analytical Procedures:**

I)*Qualitative Tests*

A. *Appearance*- visual inspection of the uniformity of pdr and color of the grains(Ref 10,p 191)

B. *Identification*. Place ca 0.2g of material in a 5-ml beaker, add 2-3 ml distd w and stir for 5 min. Decant the liq through a filter into a small beaker, Evap this to dryness and test part of the deposit(white, in the case of BkPdr) with 1 drop of 1% DPhA soln in concd $H_2SO_4$, using a white porcelain spot-test plate. A blue color indicates the presence of a nitrate. Place another portion of the deposit in an indenture of a white porcelain spot-test plate, add an equal amt of cryst thymol and 3 drops of concd $H_2SO_4$. Stir the mixt and note the color in 5 mins or more. A green color indicates the presence of a nitrate. Heat the w-insol residue in the 5-ml beaker to dryness, cool and digest with two 5-ml portions of $CS_2$ decanting these into an evapg dish. Evap to dryness at RT and examine the deposit(yel, sulfur, if the sample is BkPdr) by means of a microscope. Examine also the residue after $CS_2$ treatment(black, carbon, if the sample is Bk Pdr)(Ref 9,pp 269-73)

II. *Quantitative Tests*

A. *Bulk Density*, also called *gravimetric density* or *apparent specific gravity*, is the relation betw wt and vol of the pdr. This includes the air spaces betw grains. In the Bofors method, Ref 10,p 23, a cylindrical vessel of 100ml capacity is filled through a special funnel and then weighed without shaking. In the BurMines method(Ref 2,p 67), the so-called gravimetric method is used. US Army Specs(Refs 11 & 12) do not describe the bulk test

B. *Specific Gravity*, also called *absolute density*, is the relation betw wt and volume of grains disregarding the air spaces. The Bofors manual(Ref 10,p 22) describes two methods: Mohr-Westphal's balance and pycnometer methods. In the BurMines method(Ref 2,p 67), an apparatus called densimeter is used. In US Spec JAN-P-223A(Ref 11) two methods are described in which either a 25-ml bottle with a 10-g sample or a large two-stopcock bulb with 100-g sample is used. In both cases, mercury is used for displacing the air

C. *Granulation* is detd by separating the product under std conditions using a series of sieves of different sizes. The app is described in Bofors manual(Ref 10,p 23). A similar method is used in the US(Ref 2,p 66 and Federal Spec RR-S-366)

D. *Moisture*. In the Bofors' method(Ref 10,pp 15 & 191) a 5g sample is dried in an oven at 75° for 3hrs. In the BM method(Ref 2,p 69) a 2-g sample is spread on a 3" watch glass and dried over concd $H_2SO_4$ in a desiccator at RT for 3 days. This method is described in US Specs(Refs 11,12 & 13) as an alternate to the method in which a 2-g sample is dried on a watch glass(or in a dish) for 4 hrs in an oven at 70°

E. *Composition*. This usually includes sulfur, charcoal and K or Na nitrates. In the Bofors' Method(Ref 11,p 191), a previously dried 10-g sample of BkPdr is extracted with $CS_2$ for 16 hrs in a Soxhlet app. After removing the thimble, the solv in the flask is distilled off and the residue is dried at 70°. This gives *sulfur content*. After drying the thimble, its contents are transferred quantitatively to a previously dried and tared sintered glass crucible of medium porosity(such as Jena 1G3 or Pyrex M), in which it is treated with hot distd w until the nitrate reaction of the wash w had disappeared. After drying the crucible at 100° to const wt, it is cooled in a desiccator and weighed. This gives *charcoal content*. The *nitrate* content is obtained by difference 100%-(% sulfur + %charcoal)

In the US method(Ref 2,pp 70-72 & Refs 11, 12 & 13), the following procedure is used:

A)*K or Na Nitrate*. Transfer a known wt of a sample(ca 10g) to a 400-ml beaker, add 200ml distd w, bring to a boil and hold for 15 min on a steam bath. Filter through a sintered glass crucible and wash with successive portions, 10-15ml, of hot w until the nitrate reaction(blue coloration when tested with DPhA in concd $H_2SO_4$) of the wash w has disappeared. Dry the crucible to const wt at 70°(ca 4 hrs), cool in a desiccator and weigh. Calculate the percentage of nitrate on a moist-free basis

B)*Sulfur*. Place the crucible and contents from the previous operation in an extractor on a water bath and extract for 4 hrs with $CS_2$. Wash the residue in crucible once with

alc and once with ether using suction. Dry for 1 hr at 100°, cool in a desiccator and weigh. Calculate the percentage of S on a moisture-free basis. This operation removes only rhombic sulfur. If the presence of amorphous S is suspected, the residue must be washed, after $CS_2$ extraction, with several portions of hot aniline followed by alc & ether washes

C) *Charcoal*. If the pdr is not graphited, the residue in the crucible after detn of $KNO_3$ and S may be considered as charcoal. Det its weight by subtracting the original wt of the filtering crucible from the wt of crucible + residue. Then calc the wt of the residue as percentage of charcoal on a moisture-free basis

*Note*: Slow-burning pdr(Type II, in Ref 13) contains coal in lieu of charcoal

D) *Foreign Matter*. Examine the residue in the crucible for foreign matter such as fibers, sticks, stones, sand etc. No such matter shall be present

E) *Ash*. Ignite the crucible with charcoal in a muffle furnace or over a Bunsen Burner until all the carbon is burned off. Calculate the wt of residue as percent ash

The US Specs requirements(Refs 11,12 & 13) for various types of BkPdrs are listed above under Black Powder

Lapchenkov(Ref 2a,pp 59-60) describes the following method of BkPdr analysis:

*Sulfur* can be detd by two methods:

a)Boil in a tall 1l beaker 1g of finely divided BkPdr with 100ml $HNO_3$(d 1.4), adding periodically small amts of dry $KClO_3$ and new portions of $HNO_3$. Continue boiling until complete dissolution of sample and the color of liq becomes light yel. Dilute the soln with ca 6 volumes of w, heat to boiling and add 25ml of boiling 10% $BaCl_2$ soln. After leaving the liq overnight, det the amt of $BaSO_4$ by the usual method and calc the % of sulfur

b) Place in a 200ml beaker 0.3g of finely divided BkPdr, add 25ml of 3% NaOH soln, cover with a watch glass and boil for 45 mins. The following reaction takes place:

$$4S + 6KOH \rightarrow 2K_2S + K_2S_2O_3 + 3H_2O$$

Add 25ml of 3% $KMnO_4$ soln & few pieces of unglazed porcelain or pumice stone and boil for ca 40 mins. The following reactions take place:

$$3K_2S + 8KMnO_4 + 4H_2O \rightarrow 3K_2SO_4 + 8MnO_2 + 8KOH$$

$$3K_2S_2O_3 + 8KMnO_4 + H_2O \rightarrow 6K_2SO_4 + 8MnO_2 + 2KOH$$

Add 25ml HCl(d1.19) to dissolve $MnO_2$, filter and heat the filtrate to boiling. Add 25ml of boiling 10% $BaCl_2$ soln and leave the liq overnight. Det the amt of $BaSO_4$ by the usual method and calc the % of sulfur

*Saltpeter* is detd by boiling 2g BkPdr with w, filtering and weighing the dry residue. Here the wt of residue is C+ S and the loss in wt the saltpeter

*Charcoal* is calcd by subtracting the amt of detd S from wt of residue

*Refs*: 1)R.Escales, "Schwarzpulver und Sprengsalpeter",Veit,Leipzig(1914); physical tests, 381-89; chemical tests, 389-91; ballistic tests, 391-405 2)W.O.Snelling & C.G. Storm,"The Analysis of Black Powder and Dynamite", BurMinesBull **51**,Washington,DC (1916); physical examination 66-8; chemical examination, 69-76 2a)I.V.Lapchenkov,"Kurs DymnykhPorokhov,"GosKhimTekhIzdat,Moscow(1933)(in Rus) 3)V.Ohman & G.Laurent, ZAnalChem **107**,409-11(1936) & CA **31**,2007 (1937)(Detn of saltpeter in BkPdr using a Zeiss interferometer) 4)A.A.Azzam, MikrochimAkta **2**,283-6(1937) & CA **32**,1933(1938) (Feigl's spot tests used in analysis of BkPdr combustion products) 5)A.W.Baker,Explosives-Engr **17**,115-17(1939) & CA **33**,5661(1939)(A method for detg the burning rate of BkPdr by using an open steel pipe) 6)A.Wetterholn,SS **38**,189-92(1943) & CA **38**,4131(1944)(Detn of moisture in BkPdr) 7)Kast-Metz(1944),5-19 8)H.Henkin & R.McGill,IEC **44**,1391-5(1952) & CA **46**,8857(1952)(Expl temp of BkPdr detd in a special apparatus) 8a)A.Douillet & P. Miaud,MP **36**,277-84(1954) & CA **50**,3764(1956) (Studies of ignition and burning of BkPdr in a manometric bomb) 9)Anon,"Military Explosives", Dept of the Army Tech Manual TM **9-1910**(1955), 90-1 & 273 10)AB Bofors,Nobelkrut,"Analytical Methods for Powders and Explosives", Bofors,Sweden(1960),191 11)US Spec JAN-P -223A,"Powder,Black" 12)US Spec JAN-P -362, "Powder,Black,Sodium Nitrate" 13)US Purchase Description X-PA-PD-623, "Powder, Fuze" and "Powder, Black, Slow Burning"

**Black Powder Destruction**. If the powder is in containers(25- or 50-lb drums), they must be opened with wooden or non-sparking metal tools and if a stream or large body of water is at hand, the pdr can be dumped into it. (For detailed instruction see SR 75-70-10/AFR 68-3)

The w will dissolve saltpeter leaving sulfur and charcoal as deposits, both of which are harmless. The washings must be disposed of separately from the residue. This method cannot be used in places where anti-pollution laws exist. In this case, the pdr must be sent to the *burning ground* (qv) to be destroyed in the following manner:

a)Open one of the containers, using a wooden or non-sparking metal tool, and spread the contents on the ground in a trail(strip) not wider than 2" and not over 1-2" deep, in such a manner that no part of the trail parallels another part within a distance of 10 ft. The ground over which the trail is laid should be free of cracks or other depressions in which the pdr might accumulate and be in some confinement

b)Lay a train of combustible material(such as paper or excelsior),preferably on the down--wind side of the trail, of such a length(ca 25 ft) that the operator can reach a safe place after igniting the paper. Ignite the combustible material

c)After the pdr burns, wait until the ground cools before starting the destruction of the 2nd and subsequent containers. If space permits use a new area of ground for 2nd, etc, containers. Never burn more than one container(25 or 50 lb) at a time

d)Wash out the empty containers with w

*Refs*: 1)Anon,"Safety and Storage Manual for Explosives and Ammunition", 00 Form **5994**, Secn XI, US Army, Chief of Ordnance,Washington,DC(1928),p 3 2)Anon,"Ammunition Inspection Guide", TM **9-1904** (1944),pp 773-4 3)R.D.Leitch & P.R.Moyer,US BurMines,Inf Circ **7335**(1945),pp 3-4 4)Anon,"Ordnance Safety Manual", Ordnance Corps Manual ORDM **7-224**(1951) 5)Anon,"Military Explosives", Dept of the Army Tech Manual TM **9-1910**(1955) 315-17 6)Anon, "Care, Handling, Preservation and Destruction of Ammunition", Dept of the Army Tech Manual TM **9-1903**(1956),179

**Black Powder Fires.** BkPdr can be ignited easily by sparks, heat or friction. When unconfined, it burns with expl violence but will expl if ignited under even slight confinement. Only safety tools(such as made of wood or of non-sparking metal) shall be used when opening or closing containers. This will be done only in a bldg free from other expls & ammo or, in suitable weather, in the open at least 100 ft from the nearest magazine. The quantity at/or near such an operation shall be limited to 100 lb. If a fire should take place during these operations, one must immediately withdraw to a safe distance because of danger of expln. Every effort must be made to prevent the fire from spreading to a BkPdr magazine. If this, however, fails, firemen should be withdrawn to at least 800ft from the magazine and either stand behind a barricade or lie flat on the ground. If an expln of a BkPdr magazine should occur, all efforts of firemen must be concentrated in preventing spreading of fire to adjacent bldgs, especially magazines with expls & ammo

*Refs*: 1)"Safety and Storage Manual for Explosives and Ammunition", 00 Form **5994**,Secn XI(1928) 2)TM **9-1904**(1944),p 78-9

**Black Powder Packing, Storage, Handling, Safety Precautions, Maintenance, Inspection & Surveillance, Shipping and Transportation.** A std container for *packing & shipping* BkPdr is a commercial iron drum(25-lb capacity) complying with ICC specifications. BkPdr may also be packed for *storage* in 50-lb metallic containers or in 110 lb metal lined smokeless proplnt boxes, but the amt in each container must be limited to 50 lb. The containers must be *stored* in bullet-proof magazines used for storing expls and ammo, but never in barracks, general supply rooms, inhabited bldgs or any bldgs heated by stoves or open fires. Instruction for proper piling(stacking) the containers in a magazine are given in Ref 2,p 790. Max amt of BkPdr allowed in one magazine is 250,000 lb

As BkPdr is very sensitive to sparks, friction and heat, strict *safety* precautions must be exercised in handling it. In a bldg contg BkPdr, only safety(non-sparking) shoes must be worn and all tools and equipment must be of non-sparking materials, No work around BkPdr shall be done other than that involving the storage and handling of containers or powders. If a storage magazine has a concrete floor, it must be covered with a tarpaulin or other suitable material. If it is necessary to transfer the pdr from one container to another conductive rubber mats must be used at locations where such operations are performed (Ref 4,p 80)

*Note:* According to Ref 3,p 79,"A container will not be opened in a magazine in which expls or ammo are stored. This will be done only in a room or bldg free from all other

expls or ammo, or in suitable weather in the open at least 100 ft from the nearest magazine" To this may be added that if repacking is conducted outside, it is advisable to do it under a very light cover, such as canvas

Loose BkPdr is especially sensitive and whenever it is necessary to handle it, not over 50 lb of such pdr in open containers and not over 50 lb in closed containers(total 100 lb) must be permitted at or near such operations

If BkPdr is spilled on benches or floors, all work in the vicinity must be stopped until the pdr has been removed and the expl hazard of any remaining dust or fine particles has been removed by washing down the area with w

Most of the above operations belong to *maintenance* activities. To these may be added repainting & marking of containers, replacement of metallic caps, etc

Since BkPdr deteriorates with the absorption of moisture and the containers in which it is stored are subject to rust, a thorough *inspection* of these articles must be made at least once a year. For this, one or several containers from each lot will be opened at the time, of annual inspection and if there is any doubt about serviceability of the pdr, it must be removed to the lab for physical and chemical testing. At the same time, the containers must be inspected for holes, weak spots, etc. Damaged containers should not be repaired but removed and the contents transferred to new containers. All of these operations may be called *surveillance*

Rooms or bldgs in which BkPdr is handled must be frequently examined for the presence of BkPdr dust and all such dust must be immediately removed with w

All containers with powder intended for *Shipment* must be previously inspected and those going overseas must be crated *Transportation* of BkPdr within the USA is governed by "Regulations for the Transportation of Explosives and Other Dangerous Articles by Freight" established by ICC (Freight Tariff No 8). BkPdr is shipped as "Class A" expls which include those materials representing an expln hazard in case of fire but not in case of an accident without fire(Ref 3,pp 311-14 & Ref 5)

*Refs*: 1)Anon,"Safety and Storage Manual for Explosives and Ammunition", 00 Form No **5994**, US Army Chief of Ordnance, Washington,DC(1928),Secn XI 2)Anon,"Ammunition Inspection Guide", War Dept Manual TM **9-1904**(1944),77-8 & 790 2a)Anon,"Ordnance Safety Manual", ORD **M7-224**(1951), 14-11 & 20-4 3)Anon,"Military Explosives", Dept of the Army Tech Manual TM **9-1910** (1955),306 & 311-14 4)Anon,"Care,Handling, Preservation, and Destruction of Ammunition", Dept of the Army Tech Manual TM **9-1903**(1956), 80 & 146 5)Sax(1957),Section II 6)B.Kanouse &C.V.Ruskewicz,PicArsn; private communication (1961)

**Blainite.** An Italian mining expl utilizing discarded military propellants. It consisted of *Ballistite* or *Cordite* (previously pulverized) 60, AN 25, $NaNO_3$ 10, $Pb(NO_3)_2$ 3 and $Ba(NO_3)_2$ 2%

*Ref*: Molina(1930),362

**Blake Explosive,** proposed in 1865 for filling grenades and torpedoes; consisted of K chlorate and sulfur. It was the predecessor of *Sprengel Explosives*, known as *Cheddites* or *Street Explosives*

*Ref*: Stettbacher(1933),309

**Blanche Dynamite** (White Dynamite). An old Austrian dynamite, as invented by M.Diller, consisted of NG 70, guhr contg limestone 19.35 & woodpulp 10.65%

*Ref*: Daniel (1902),73

**Blanche Dynamite de Paulilles.** An old expl similar to Dynamite No 1 and contg NG 70-75 & siliceous earth 30-25%

*Ref*: Daniel(1902),73

**Blanche Poudre.** Fr for White Powder. See B (Poudre)

**Blank Ammunition.** See under Ammunition and Weapons or Arms,IIA(According to Service Use), Vol 1,p A383-R

**Blank Cartridge** is a cartridge charged with a blank powder(qv)

**Blank Cracker** is a pyrotechnic device with an expl chge and fuze designed to serve as a dummy weapon for simulating a live weapon such as a hand grenade. It should explode with a loud crack without any danger to personnel or surrounding objects. One type of such blank

-crackers was recently patented in England *Ref*: K.Hjellnes(Oslo, Norway), BritP 726302 (1955) & CA (1955-60)-not found

**Blanketed(Cased or Enveloped) Explosives.** Same as Sheathed Explosives

**Blanketing Compositions for Blasting Explosives.** See under Sheathed Explosives

**Blank Powder** is used in firing signals, for saluting, for manoeuvres and, in fact, in all cases where it is required to make noise of firing without ejecting a projectile. Instead of projectiles felt wads are used. As the wads do not offer resistance to the expansion of pdr gases, the pressure in the weapon decreases after firing almost to zero. In order to offer greater resistance to the pdr gases the cartridge is sometimes provided with a "mock shot" made of hollow wood or other suitable material which breaks up at the muzzle of the gun. The pdr used in blank firing should be rapid-burning. The desired rate of burning may be achieved either by using partially gelatinized materials, similar to those used in bulk sporting proplnts(See Bulk and Condensed Powders) or by using finely divided completely gelatinized smokeless proplnts. One of the most common smokeless blank proplnts. is *EC Blank Fire Powder* (qv). It has been used in cal .30" blank ammunition BkPdr is still used in some types of blank ammo

*Refs*: 1)Marshall I(1917),334-5 2)Ohart(1946) 30 3)Anon,"Military Explosives", Technical Manual TM **9-1910**(1955), 249

**Blast.** A phenomenon caused by a rapid expansion, at high pressure and temperature, of the gases resulting from an explosion(see Blast Effects)

## BLAST EFFECTS IN AIR, EARTH AND WATER

(Air Blast Effects, Blast Energy, Blast Impulse and Blast Pressure)(the latter is called Detonations-druck in Ger)

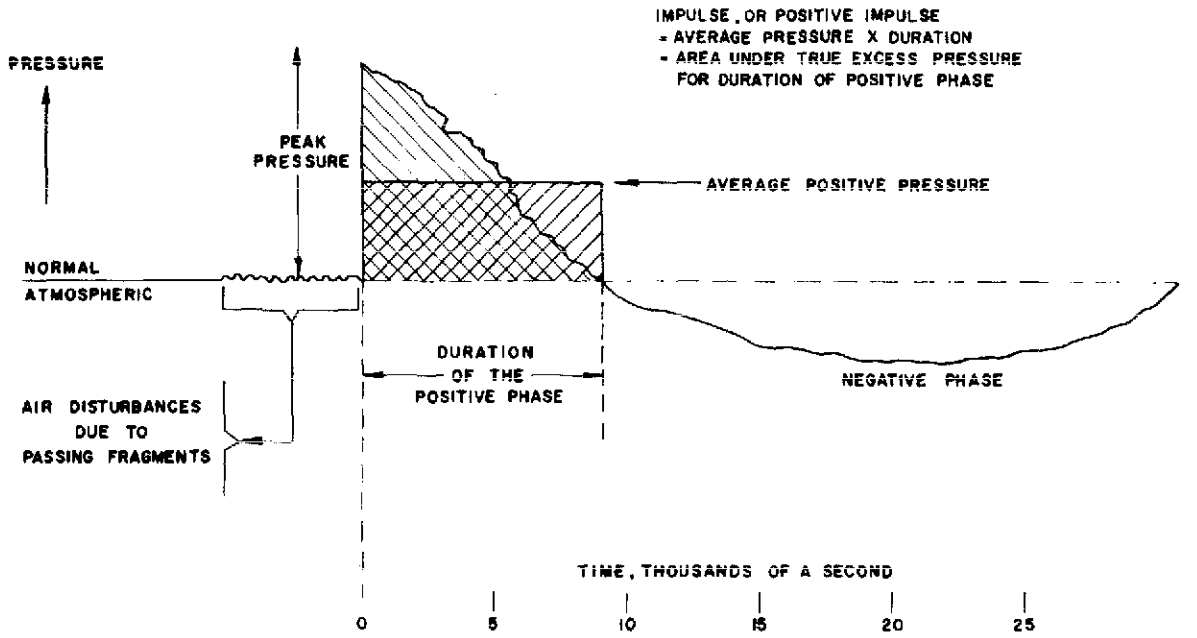
In military operations it is a known fact, proved during WWII, that greater damage can be done to installations by blast effects from bombs than by metal fragments from bombs or other conventional projectiles. Blast waves act as a severe earthquake and cover a circular area, whereas bomb fragments do damage only at random points of impact

When a bomb type HE(such as TNT, Comp B, HBX or Torpex) detonates, the solid chge is rapidly converted into gaseous products. This process, occurring in approx 0.0001sec developes very high temps & pressures. These values vary with the chem compn of the expl but their order of magnitude is 100,000 atms (700 tons/sq in) press and 3000° (5400°F) temp. Of the total energy available from the expl, as much as ½ may be used to expand the casing (bomb body) and the remainder is used to compress the surrounding environment. This latter *energy* is responsible for the blast effects

Prior to WWII *Trauzl Lead Block Tests* (See Vol1,pXXV) were made on the expl itself and bombs were detonated in an enclosure te determine the number and penetrating power of the bomb fragments. Although both tests give valuable info, neither is directly related to the blast effectiveness of an expl. Quantitative blast measurement techniques were developed in England in 1938 and later in the USA at Aberdeen Proving Ground (APG)(Refs 4 & 12, p 86) and Princeton Univ in 1941 & 1942(Ref 13). (See brief description of blast measurement methods under Blast Meters)

Many investigators have made experimental studies of the blast from bombs and from bare charges (Refs 2,7,9,11 & 26). Theoretical discussions of the formation of the blast waves have been reported by Kirkwood & Brinkley (Ref 5), Cole (Ref 10), Taylor (Ref 14), Berry et al (Ref 18) and others (Refs 12, p 58ff; 21 & 22)

**Blast Effects in Air** *(Air Blast Effects)*. When an expl charge is detonated in air, the gaseous products expand rapidly and compress the surrounding air so that it moves outward with high velocity, thus initiating a *shock wave*. This layer of compressed air is bounded by an extremely sharp front, called the *shock front*, in which the pressure rises abruptly. The shock front moves outward with an initial velocity much greater than that of sound but, after a short distance, the velocity decreases rapidly. The gaseous products of deton move as a strong wind behind the shock front and are prevented by their own inertia from decreasing as rapidly as the pressure at the point of deton. As a result, there is produced a *rarefaction effect* and a point of reduced pressure, which condition trails the shock front. When the pressure becomes less than atmospheric, the wind rever-




TYPICAL PRESSURE–TIME RECORD FOR THE BLAST FROM A BOMB

ses in direction and blows back toward the point of deton. The shock front, the high press area behind it and the trailing rarefaction condition, form a complete wave which is called *blast or shock wave*

In expressing the blast effect of an expl, it is necessary to describe both *peak pressure and impulse:*

In the above fig of a typical blast wave, peak pressure is the press increase at the shock front or the highest press in the wave minus atmospheric press, and is a measure of the max force exerted by the blast wave. Impulse is mathematically equal to the *positive phase* and is a measure of the force multiplied by the duration. The *negative phase* lasts considerably longer than the positive phase but the max negative press is only a fraction of the max positive press (See Ref 12,p 65ff)

In general, both peak press and impulse must exceed certain min values in order to demolish various structures. Structures that are strong and light wt, with respect to the area presented to the shock front, require high peak press but no great impulse; while heavy but relatively weak structures require considerable impulse but not such a high peak press to cause demolition. For example, window glass requires a moderately high peak press but only a low impulse value; while a brick wall withstands only a small peak press if the impulse value is high (Ref 2, 13 & 25). Bernal(Ref 1) studied the destructive effects of blast on living organisms and various objects and found that a press wave of 6 kg/cm$^2$ kills a man while 0.07 to 0.7 kg/cm$^2$ destroys window panes. A comprehensive study of pathological effects of blast from expl devices in air, underground and underwater is reported by Valade (Ref 20)

The relative air blast effectiveness of various expls is indicated in the following table: (See also Refs 6,13,16,17,19,21,25, 26&27)

See Chart Next Page

| Explosive | Peak pressure (at equal distances) | Effectiveness against load-bearing wall construction | |
|---|---|---|---|
| | | Radius | Area |
| Torpex (RDX/TNT/AL: 42/40/18) | 122.5 | 125 | 156 |
| HBX (RDX/TNT/AL/Wax: 40/38/17/5) | 117.5 | 120 | 144 |
| Minol ($NH_4NO_3$/TNT/AL: 40/40/20) | 115 | 117.5 | 138 |
| Tritonal (TNT/AL: 80/20) | 112.5 | 117.5 | 138 |
| DBX ($NH_4NO_3$/RDX/TNT/AL: 21/21/40/18) | 112.5 | 112.5 | 127 |
| RDX Comp B (RDX/TNT: 60/40) | 110 | 110 | 121 |
| Ednatol (Halite/TNT: 57/43) | 105 | 105 | 111 |
| TNT | 100 | 100 | 100 |
| Picratol (Expl. D/TNT: 52/48) | 100 | 100 | 100 |
| Amatex ($NH_4NO_3$/RDX/TNT: 43/9/48) | 100 | 97.5 | 95 |
| Amatol ($NH_4NO_3$/TNT: 50/50) | 95 | 87.5 | 77 |

Relative blast effectiveness of various explosives. TNT= 100

**Blast Effects Due to Reflected Shock Waves.** Blast waves are reflected from solid surfaces but not in the same manner as sound and light waves are reflected. When a bomb is detonated at some distance above the ground, the shock wave spreads out almost spherically until it strikes the ground. This initial wave, called the *incident wave,* is reflected by the ground surface. At a certain distance along the ground, from the point immediately below the bomb, the reflected wave combines with the original or incident wave to form a third wave which has a vertical front at ground level. This third wave is called a *Mach wave* and the point where the three waves intersect is called the *triple point.* At the triple point, where the incident wave is reinforced by the reflected wave, both peak pressure and impulse are at a max and each is considerably higher in value than that exerted by the original shock wave at the same distance from the point of expln. The Fig on next page illustrates the formation of a Mach wave and shows the path of the triple point

Thus by controlling the height of deton, it is practicable, utilizing the phenomenon of Mach reflection to control the region of max blast effect (See Ref 12,p 65ff)

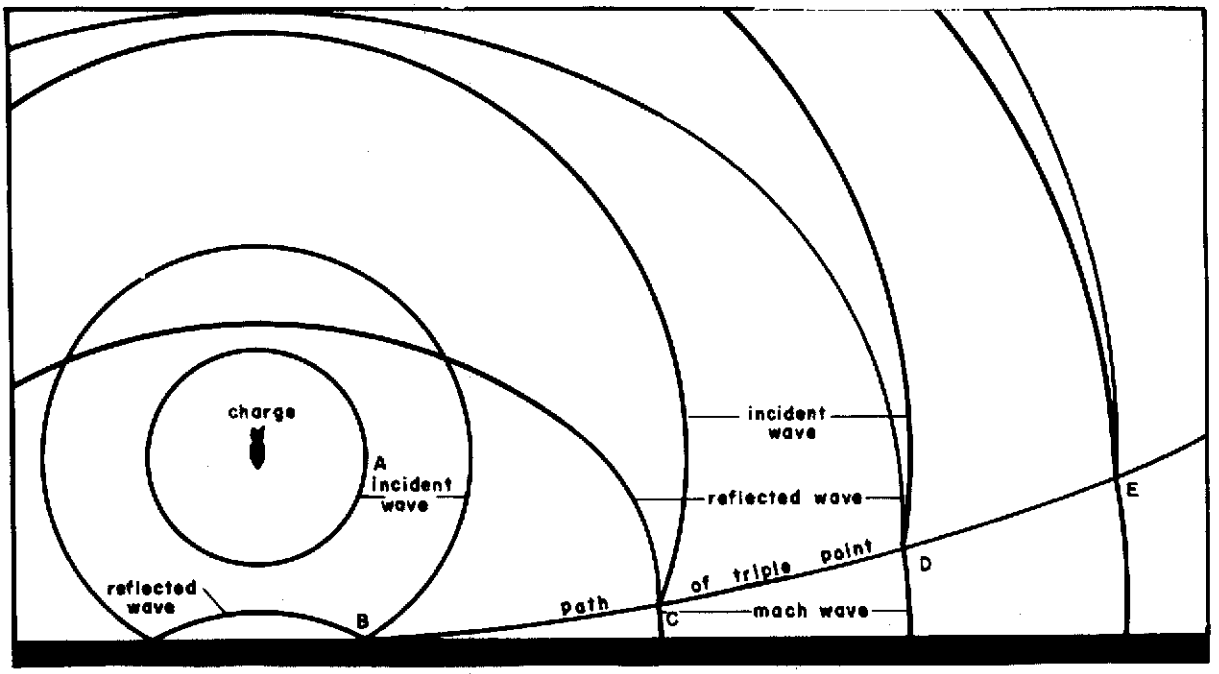
Blast effects are enhanced also by confinement, due to reflection of blast waves by the confining surfaces. For example, a blast wave travelling through a tunnel, corridor, trench or even a street, decreases in intensity much more slowly than the same wave in the open. If a bomb detonates within a building, there is considerable reflection of the blast wave, even if the walls are demolished. The overall effect of confinement of blast waves is to increase the *vulnerable radii* of demolition and visible damage(Refs 3,13,19&25)

The underground and underwater blast effects of an expln are more comparable with its open-air effects than with those observed under confinement(Ref 19)

**Blast Effects in Earth** (Underground Blast). An expl chge which is detonated while buried deeply in earth exerts pressure almost entirely on the earth about it and causes movement effects over a distance known as *radius of rupture.* If the depth of burial is less than the radius of rupture, the expln products blow through the surface of the ground and form a roughly circular depression known as a *crater.* An expln on the surface of the ground makes a shallow crater, which may have a greater diam than that produced when the expl is buried. This is due to the scouring action of gases projected downard from the expl chge

Important factors in crater formation are the type of earth cratered and the type of expl used. Expln of a moderate chge in soft,

MACH REFLECTION




FORMATION OF "MACH WAVE" AND "TRIPLE POINT"

swampy ground makes a relatively huge crater, while in a rock formation only a small crater will be formed. An expl of low deton rate, that produces a large vol of gases, may form a larger crater than TNT, if the chge is well below the surface and the ground is not too hard or rocky. If the chge is on the surface, a low-rate expl makes a smaller crater than TNT because of the weaker scouring action of the lower velocity gases

The volume, in cu ft, of a crater produced on *average* soil by coml dynamite is given by the equation: $V=0.4W^{\frac{2}{3}}$, where W is the wt of dynamite in lbs. This equation is not applicable to military bursting chge expls as they are more effective cratering agents than are coml blasting expls. Since cratering effect is considered to measure to some extent the demolition effects of GP bombs, these bombs are sometimes tested for size of crater produced. The formula $V=4.13W$, where V is the vol of crater in cu ft and W is the wt of expl in lbs, has been found to apply for 500 & 1000-lb TNT bombs

If an expl is buried at a depth exceeding the radius of rupture, the compression effect downward and horizontally and the lifting with subsequent subsidence cause a depression on the surface known as *camouflet* (Refs 19 & 25)

Mixts of AN with high percentages of Al are very effective for air blast, underground and underwater use because of their long maintenance of sustained pressure, despite their low brisance. The use of cratering operations in the field has led to the development of special blasting expls (qv), including AN compns. These are not to be confused with expls of high deton rate, such as Comp C-3 & Comp C-4, which are used to produce earth shocks(qv)(See Refs 6,17 & 26)

**Blast Effects in Water** (Underground Blast). Extensive studies of underwater explns were conducted by A. Stettbacher and some of his results are given in Ref 23. The deton of HE underwater results in shock waves of extremely high pressures, which decay rapidly with distance from the chge(Ref 15). Since the total damage is due to both the shock wave and the subsequent bubble pulses, these effects must be separately evaluated(Ref 8). One measurement to make is that of the *periods of oscillation* of the bubble, that is, the time intervals between successive minima in the bubble radius. The length of the bubble period is related, to the energy left after passage of the shock wave, by equations discussed by Swift, Jr & Decius

(Ref 8). In general, the longer the bubble period, the greater is the energy
A second measure of the energy may be obtd from a study of the max & min radii of the bubble. By a combination of radius and period measurements, calculations of energy and other parameters have been made(Ref 8). Working with a liq contg gas bubbles, Campbell & Pitcher(Ref 24) found evidence that, in a collision between two shock waves moving in opposite directions, the strengths of the two shocks are unaltered by the interaction between them. Cole(Ref 10) considers in detail the sequence of events in an underwater expln. (See Ref 12,pp69-71 and also Depth Bombs & Antisubmarine Bombs under BOMBS)
*Refs:* 1) J.D. Bernal, PrRoyInst (Gt Brit) **31** II, 235(1941) 2) Ya. B. Zel'dovich, RabotyKhimInst-AkadNauk **1941-43,** 214 3) J.R. Newman, "The Tools of War," DoubledayDoran(1943), 360 4)Anon, APG "Ordnance Proof Manual" OPM **40-34**(1944) 5) J.G. Kirkwood & S.R. Brinkley,Jr, "Theory of the Propagation of Shock Waves from Explosive Sources in Air and Water," OSRD Rpt **4814**(1946) 6) Anon, "Comparison of Blasts of Different Explosives," HEC Translation, Kummersdorf, April **1944** (147 pictures of explns) 7) G. Grime & H. Sheard, PrRoySoc **187A,** 357-80 (1946) & CA**41,** 1437(1947) 8) E. Swift, Jr & J.C. Decius, "Measurement of Buble Pulse Phenomena" III, UERL Woods Hole Oceanographic Instn, NAVORD Rpt **97-46**(1947) 9)E. Dubois, RevScientifique (Belg-Fr) **84,** 323 (1948) 10) Cole, Underwater(1948), 3-13 11) T. Urbanski, PrzChem **4,** 487(1948) 12) W.A. Noyes, Jr, Edit, "Science in World War II, OSRD Chemistry" (1948), 58ff&84-7 13) W.R. Tomlinson, Jr, "Blast Effects of Bomb Explosives" (1948) (PA Tech Div Lecture, 29pp) 14) G. Taylor, PrRoySoc **201A,** 159-74(1950) 15) H.G. Snay & J.H. Rosenbaum, "Shockwave Parameters in Fresh Water for Pressures up to 95 Kilobars," NAVORD Rpt **2383**(1952) 16) Armament Engrg (1954), 185-97 17) Coll, "Symposium on Blast and Shock Waves," HA, England (1955) 18) F. Berry et al, PrRoySoc **227A,** 258-70 (1955) & CA **49,**7249 (1955) 19) TM**9-1910** (1955), 72-6 20) P. Valde, MP **37,** 367-412(1955) 20a) O.E. Sheffield, PATR **2353** (1956)(C)(Blast props of expls contg Al or other metal additives) 21) Cook (1958), 353ff 22) D.W. Boyer et al, "Blast from a Pressurized Sphere", Univ Toronto UTIA Rpt **48** (1958) 23) PATR **2510** (1958), Ger 212-13 (Unterwassersprengstoffe) 24) I.J. Campbell & A.S. Pitcher, PrRoySoc **243A,** 534-45 (1958) 25) C.G. Dunkle, "Blast Effects in Air, Earth and Water", PA-Stevens Inst Technol Syllabus, Session **26** (1958), 311-19 26) H.J. Goodman, "Compiled Free-Air Blast Data on Bare Spherical Pentolite", BRL Rpt **1092** (1960) 27) G.F. Kinney, "Explosive Shocks in Air," Macmillan, NY (1962)

**Blast Effects, Measurement of.** See under Blast Meters

**Blast-furnace Dust**(Gichtstaub in Ger). It was used in some expl compns *Ref:* Kast-Metz (1944), 467

**Blastine.** A safety expl consisting of a mixt of $NH_4ClO_4$, $NaNO_3$, DNT & 5% paraffin wax(Ref 1). It was claimed by Kedesdy to be 50% more powerful than dynamite. According to Barnett(Ref 3) this is a Swedish expl, but Stettbacher(Ref 4) and Thorpe (Ref 5) report a British expl called Blastine which consists of $NH_4ClO_4$ 60, $NaNO_3$ 22, TNT 11 & paraffin 7%. Marshall (Ref 2) notes that the expl Blastine was used extensively during WWI. Kostevitch (Ref 3a) gives for a Blastine used during WWI: $NH_4ClO_4$ 63, $NaNO_3$ 23, DNT 8 & parrafin wax 6%.
*Refs:* 1)E.Kedesdy, SS **3,**97(1908) 2)Marshall **1**(1917),387 3)Barnett(1919),112 3a)M.M. Kostevitch, "Burning Ground", Imp d'Art Voltaire, Paris(1927),40 4)Stettbacher(1933),316 5) Thorpe 4(1940),464

**Blasting.** A process of loosening rocks, earth, coal, ores and other materials by the use of expls is called blasting. The blasting action may be that of a shattering, percussive or heaving nature, depending upon the type of expl used and the method of placing it within or near the material to be blasted

*Limiting charge* is defined as the max permissiblechges ofan expl used in gas-endangered mines. Seleznev(Ref 4) tested the validity of this concept by firing charges of various wts (including chges exceeding considerably the wt of a limiting chge) of safety and unsafe expls. The limiting chge concept proved to be without foundation in fact, provided the chge was made to do work, that is, spend itself on blasting coal or rock. If the chge misfired or was faultily placed, then any wt of it(safety or unsafe expls is dangerous. In view of these results, Seleznev (Ref 4) suggested a revision of the safety rules

Suzuki (Ref 3) patented an app with liq $CO_2$ expl to be used instead of dynamite in coal mines. Jinda et al (Ref 6a) reported that the toxic gases $CO_2$, CO & $NO_2$ are evolved from exploded cartridges in testing galleries and in metal ore mines. Lechner in Explosivst **1959,** 33-6 discusses poisoning by gases produced on blasting

Numerous handbooks, pamphlets and other refs describing the blasting process are available. See also Ammonium Nitrate Blasting Explosives, Vol 1,p A341; Ammonium Nitrate Dynamite, Vol 1,p A355; Ammonium Nitrate Gelatin, Vol **1,** p A367; and Blasting Explosives in this vol

*Refs:* 1)Colver(1918),485ff & 560 2)Ensign-Bickford Co, "Efficient Blasting & Prevention of Blasting Trouble",Pamphlet(1941),22pp 3)Y.Suzuki, JapP **3,4** &**5** (1950) & CA **46**,8376(1952) 4)A.I. Seleznev,Ugol' **26**, No 5, 29-30(1951) & CA **45**, 8248(1951) 5)Blasters' Handbook(1952) 6)F. Weichelt,"Handbuch der gewerblichen Sprengtechnik",Marhold,Halle/Saale(1953) 6a)T.Jinda et al,JIndExplsSoc(Japan)**14**,210-12(1953) & CA **49**,11281(1955) 7)B.Stoces,"Introduction to Mining",Lange, Maxwell & Springer,London NW, Vols 1 & 2(1954) 8)H.Stapf,"Bergbauchemie", Fachbuchverlag,Leipzig(1954),427pp 9)Imperial ChemIndustries Limited,"Blasting Practice", Pamphlet, 2nd Ed, The Kynoch Press, Birmingham (1956) 10)O.Kühnl, "Handuch der Sprengtechnik", Verlag des Osterreichischen Gewerkschaftsbundes, Wien(1958), 155pp 11)Ministry of Power, "The Use of Explosives at Quarries", HMSO,London (1961),60pp

**BLASTING CAP** (also called Commercial Detonator) (Zündkapsel Zünder or Sprengkapsel in Ger; Detonateur in Fr; Detonator in Rus; Detonadore da mina in Ital and Cebo or Capsula detonante in Span)

When black powder was used exclusively for blasting, charges were exploded by igniting them with miner's fuse, or by other igniters. When NG and dynamite were invented, it was found that they could not be exploded by such means of ignition, hence a different device was needed-one which produces a deton wave. The problem was solved by Nobel in 1867(BritPat 1345) with his invention of the blasting cap. The first cap consisted of a copper cylinder closed at one end and partially filled with MF, which was exploded by the flame of a miner's fuse. The explosion of MF produced a deton wave of great intensity, which caused the expln of the dynamite chge. The charge of MF was varied to provide the initiating strength desired

The modern blasting cap may be defined as a device intended to initiate by means of a detonating wave a HE, coml or a military demolition chge. If such a device is used as a part of an expl train in a projectile or a bomb, it is called a "Detonator" (qv)

Blasting caps may be of either the non-electric or electric type:

I) *Non-electric Blasting Caps* may be subdivided into single component and compound(or composite) caps

a) *Single-component Cap* consists of a small metallic tube closed at one end and partially filled with an Initiating Composition(see under Blasting Caps, Charges and Compositons for). A piece of safety fuse(Bickford fuse) with a freshly-cut end, pricked with a pin, is inserted into the open end of the cap and pressed firmly against the charge. With the aid of a special device, the open end of the cap is crimped tightly(as near the top as possible) around the fuse, taking care not to squeeze the cap near the explosive chge because of the danger of inducing an explosion. The cap is then inserted in a cartridge or block of HE and the fuse is ignited by the flame of a match or squib. The flame of the fuse ignites the initiating mixt causing it to explode. The deton wave thus created causes the expln of the main chge(dynamite cartridge etc)

These blasting caps are usually made in eight strengths, No 1 the weakest and No 8 the strongest The present practice in the US is to manuf only No 6 and No 8 caps. The single-component No 6 contains a mixt of 0.8g MF with 0.2g $KClO_3$; the No 8 cap contains 1.6g MF + 0.4g $KClO_3$ or their equivalents

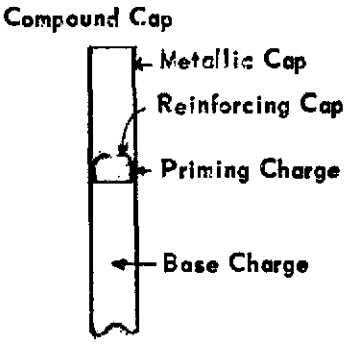
b)*Compound Cap.* Some HE's such as TNT, PA, RDX compositions, Pentolite etc, cannot be initiated with certainty by either a No 6 or No 8 cap and it is necessary to combine them with a booster or to use a cap with two components(layers), one of which is an initiating (primary) charge(such as MF) and the other is a base(main or secondary) charge (such as pressed PETN). In these caps the base charge acts as a small booster

A typical example of such caps is one which consists of a small metallic capsule(Cu, Al or gilding metal) $1^1/_8$ to $1^7/_8$" long and $^1/_4$" in diam, press-loaded at the base with tetryl, PA, PETN, RDX, HNMnt or loose TNT to form a main chge(ca 0.4g for No6 cap and 0.55-0.9g for No 8 cap). Above this is placed a layer of priming expl, such as MF w/wo $KClO_3$ & $Sb_2S_3$(ca 0.4g for No 6 cap and ca 0.5g

for No 8 cap),or LA/LSt(ca 0.2g for No 6 cap or 0.25-0.3g for No 8 cap). One of the modern No 8 caps contains 0.55g PETN & 0.25g LA. There are also larger caps, such as US Army Special Cap described below and No 16 cap mentioned in USP 2860041(1958). The latter cap consists of a large cap contg a base chge of PETN into which is slipped a regular No 6 cap thus forming a single unit equivalent to 1.5g PETN(base chge) & 0.25g LA(priming chge)(Ref 31)

MF is used now only in some foreign countries, but very seldom in the US(Ref 32)

In order to improve the performance of the cap, the initiating chge is sometimes covered with a *reinforcing cap*. This is a small perforated cap made to fit snugly against the inner wall of the main cap. Reinforcing caps are used only with MF chges and are not required with LA chges. With these caps the safety fuse is inserted and crimped as described for a single charge cap. In these caps the deton wavé created by an initiating expl is reinforced and speeded up by the deton of the base chge expl, such as tetryl, which possesses a much higher deton vel than MF, LA or any other initiating expl. This reinforced detonating impulse will explode most expls of low sensitivity(See Fig)




At the present time, the DuPont Co manufactures two standard No 6 blasting caps, one with an Al shell 1 3/8" long and the other with a Cu shell 1 1/2" long. Each has about 3/4" open space above the chge for inserting the fuse

Two No 8 caps are also manufd, one with Al shell 1 5/8" long and one with Cu shell 1 7/8" long, but they are not used extensively in coml blasting because No 6 caps are strong enough to detonate most expl. They are used, however, for military purposes

In order to intensify the deton effect of a blasting cap, the closed end of the capsule("business end") is indented towards the inside thus utilizing the Munroe(Shaped Charge) Effect. Some investigators question the value of this improvement

The compound caps described above are also called "two-part detonators" because they contain two layers: priming and base

A stronger cap, now called US Army Special Blasting Cap, designed by the US Corps of Engineers also belongs to the compound type. It is described here and also in Ref 30

*Western Big Inch Blasting Caps,* manufd by Olin Industries Inc, East Alton, Ill, are made of Al and contain RDX as a base chge. They are 1 1/8" long and 15/64" in diam and are about as powerful as the 1 5/8" long conventional cap. Because of their smaller size, there are some advantages in storing and handling them

It is also possible to prep three-component caps, similar to detonators of the same type(see under Detonators)

It is of interest to note that compound caps and detonators were developed in the US, by the DuPont Co, as early as 1912, but it was not until 1916 that a real advance was made when tetryl was first used for the base charge

Principal uses of non-electric blasting caps are in quarry and agriculture work and in ore mining

II) *Electric Blasting Caps* (also called Exploders, Electric Initiators or Detonators, or Fusees)

Since non-electric caps are fired by a safety fuse, the time of firing is governed by the length of fuse and its burning rate; consequently it is not practicable to use these caps for firing several shots simultaneously, as is required in most blasting operations. For this kind of work, elec blasting caps are of great advantage

Electric Blasting caps may be divided into "high tension" and "low tension" types

*Historical.* The original elec cap was invented in 1745 by Dr Watson of England and were improved by Benjamin Franklin in 1749. In Franklin's cap, the gap between the two wires was encased in a charge of compressed BkPdr which acted as igniter for the main chge of BkPdr. This device could not detonate the chge but only ignited it and therefore could not be used for dynamite or other HE. Franklin did not exploit his invention and it was forgotten until 1830, when Moses Shaw was granted a USPat for a similar device in which charges of gunpowder were fired simultaneously by elec current through the use of a priming compn containing fulminating silver and gunpowder. The device was not satisfactory and Shaw, with the assistance of Dr R.Hare, constructed another device which was the first "low tension" cap. It contained a fine wire, which was heated to incandescence by means of elec current from a battery. As batteries were not convenient for

field use, Baron von Ebner of Austria, in the 1850's, invented the first elec friction machine suitable for field use. The machine was improved in 1869 by H.J.Smith of Boston and was used in the blasting of the Hoosac tunnel. Mowbray modified it and called it a "Powder Keg", but it was not as good as the original device of Smith. The first magneto-electric apparatus was invented in 1856 by Sir C.Wheatstone while working for Sir F.Abel

A)*High Tension Cap* contains a sensitive priming mixt packed around a break(gap) between two pieces of wire; the outside ends of the wires are connected to two poles of a magnet or other app producing a high tension current. When the circuit is closed, a spark jumps across the gap between the wires and ignites the primary mixt. These caps have been practically superseded by:

B)*Low Tension Caps*. Electric blasting caps presently used in the USA consist of a cylindrical metal shell containing a detonating base chge, an ignition compn and an elec firing device having a high-resistance wire(bridge) between the two leg wires of the firing circuit. When the current is applied to the elec circuit(either by blasting machine or from a circuit connected to a power line), the bridge is heated to incandescence thus firing the ignition compn. This in turn acts on the initiating compn(such as MF, LA, etc) and this detonates the base chge, such as Tetryl, RDX or PETN. Sometimes, as in the "bridge plug type" caps, base and initiator chges are combined in one chge(see below). Because of the danger of detonation from stray ground currents, strong radio frequency impulses, ar accidental closing of the elec circuit, elec cap leads and circuits are always short-circuited until immediately before firing

Burrows et al of DuPont Co(Refs 9 & 10) describe the following types of elec caps:

a)*Bridge Plug Type* (Type 1) contains base chge (such as Tetryl, RDX, or PETN) combined with priming expl(such as LA). On top is placed plastic ignition chge(such as Ag or Hg salt of chlorinated azidocarbonamidine in NS gelatinized with amyl acetate; Pb picrate or LSt or Ag azide in NS jelly; mixt of Cu acetylide, K chlorate & carbon in collodion). A high resistance bridge wire, connected to two leading (leg) wires of the firing circuit, is imbedded in the mixt. These wires are held in a fixed space relationship by means of a plug, usually shaped like a truncated cone. A waterproofing compn, covered with cast sulfur, is placed on top of the cone. In order to prevent the cap from accidentally being fired by static electricity developed in the human body, from friction or from stray radio frequency waves, one of the leading wires touches the wall of the cap at some distance from the ignition compn

b)*Concave Plug Type* (Type 2) contains a base chge (usually Tetryl, RDX or PETN) in the bottom of the cap, covered with a smaller chge of initiating expl(such as MF or LA). The bridge wire is imbedded in an ellipsiod consisting of a cemented ignition compn which is generally in a plastic condition when applied and hardens on drying(See Type 1 Cap). In order to facilitate the application of this compn to the bridge wire, the smaller base of the conical plug holding the bridge wires is made concave

c)*Match-head Type* (Type 3) contains in the bottom of the cap, a base chge(such as Tetryl, RDX or PETN) covered with an initiating chge(MF or LA). The ignition device consists usually of a flat strip of insulating material, the two faces of which are covered with metallic foil each soldered to a leading wire. A bridge wire passes around the end of the strip and connects to the ends of the leading wires. After this, the bridge wire is dipped into a plastic ignition compn which dries to form a hard, tear-drop shaped pellet similar in appearance to an ordinary matchhead. For this may be used Cu acetylide or Ag azide or LSt(yel variety) in NS gelatinized with amyl acetate; mixt of Cu acetylide K chlorate & carbon in collodion. The remaining parts are the same as in Types 1 and 2 (See also Ref 8)

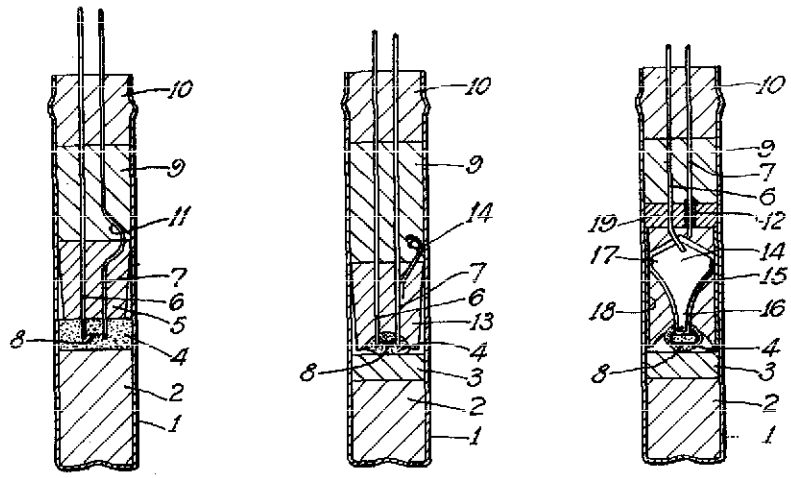
See Figure next page

Copper brass and aluminum may be used as material for the cap(shell) itself

Many other ignition compns have been patented such as: bis-triethyl lead styphnate, triethyl lead -basic lead styphnate, triethyl lead azide, mono -triethyl lead azo-aminotetrazole, bis-triethyl lead azoaminotetrazole, triethyl lead azidodithiocarbonate, diethyl lead diazide & bis-basic diethyl lead styphnate, etc. The ignition compns mentioned above have an "overall lag" of less than 0.0009 secs when fired at 12 amps. but in some cases this lag is even smaller, viz, 0.0002, 0.0003, 0.0004, 0.0005 or 0.0006secs

In addn to the initiating compds mentioned above(MF and LA) the following may also be used: LSt, DADNPh, TATNB, Cyanuric Triazide, Tetracene or a mixt of LA 80-90 & K chlorate 20 -10%(See also Additional References on Blasting Cap Compositions, which are given below)

*A special blasting cap*, particularly suitable in




Type 1 Type 2 Type 3

**ELECTRIC BLASTING INITIATORS**

1 – Metal capsule or shell
2 – Base charge
3 – Priming charge
4 – Ignition composition
5 – Bridge plug
6 – Leg wire
7 – Leg wire
8 – Bridge wire
9 – Waterproofing compn
10 – Sulfur seal
11 – Elbow in leg wire
12 – Insulation
13 – Concave plug
14 – Elec connection between shell wall & leg wire
15 – Insulating material
16 – Tab
17 – Shoulder
18 – Paper cylinder
19 – Elec conducting plug

seismographic explorations for mineral or other deposits, was invented by Burrows & Handforth (Ref 4). This cap contains a bridge wire which cannot be melted by the passage of a discharge from the ordinary elec blasting machine(manually operated elec dunamo) with max voltage of 225 volts and an instantaneous peak amperage of 15amps. The wire is 0.005" diam(in lieu of 0.0025" Ni/Cr wire which usually melts by current of blasting machine) and is constructed of an alloy: Ni 80, Cr 20. The passage of the current through this wire heats it to such an extent as to fire any of the ignition mixts in use at present

*Delay electric blasting caps* are similar to regular elec caps except that a delay element is inserted between the electrical firing element and the detonating (base) chge. They are used to detonate charges of dynamite in rotation, giving more accurate timing of the delayed shots than is possible with non-electric caps and fuses. The delay time of each intervening cap is such as to prevent overlapping between delay periods. These periods are usually equal to 0.8-0.9 secs(See also Ref 22,pp 97-9)

Delay caps are manfd in the US by DuPont Co, Olin Mathieson and other concerns

*US Army Special Blasting Caps*, formerly known as *Special Army Engineers' Blasting Caps*. Many of the demolition expls used by the military forces in the field are HE's such as compressed TNT, compressed NS expl and Composition C-3 and C-4 cannot be detonated with certainty by coml blasting caps. Special larger caps, both elec and non-elec are made for this purpose:

The *nonelectric cap*, called *Type I* consists of an Al alloy "52S" shell ca 2.35" long and ca 0.235" in diam, closed at one end. The charge consists of 13.5 grains of PETN or RDX (base chge) and a sufficient amt of LA(priming chge) to insure complete detonation of PETN or RDX. Both chges are compressed into the shell so that not less than 0.75" above the chge is left empty for insertion of a suitable safety fuse

The *electric cap*, called *Type II* consists of an Al alloy "52S" shell ca 3.15" long and ca 0.275" in diam, closed at one end. The charge consists of 13.5 grains of PETN or RDX compressed into the shell. A priming chge(LA) and igniter are then

inserted. The igniter bridge wire is connected to terminals of two copper leading wires, each 12-ft long. The cap is sealed to make a waterproof assembly(Ref 30,pp 2 & 3)

(Compare with Detonators and with Blasting Squibs)

*British Blasting Caps* (Commercial Detonators). The nonelectric caps are described in Refs 12,20,23 & 26. Although the majority of caps used in Brit industry are either No 6 or No 8, sizes ranging from No 1 to No 10 are available for experimental or other purposes. Until recently the detonator chge consisted of a mixt of MF & K chlorate, but this has been replaced very largely by ASA-Tetryl or ASA-PETN detonators(See ASA in Vol 1,p A493 of this Encyclopedia and Ref 26,p 55). Generally speaking, ASA detonators are stronger than fulminate detonators of corresponding numbers, but Briska Detonators are even stronger

*British Electric Detonators* are described in Ref 26,pp 56-65

*British Delay Detonators* are described in Ref 26, pp 69-85

*French Detonators*. See Refs 4 and 6

*German Detonators* are described in Refs 7 & 27 (See also Refs 1,2,5 & 19)

*Italian Detonators* are described in Ref 24a

*Russian Detonators*. See conf Ref 25(8 unclassified Refs)

*Spanish Detonators* are described in Ref 17 (See also Refs 17a & 24)

*Refs*: 1)C.Herlin,SS **15**,137-40(1920) 2)Naoûm, Expls(1927),187 3)Van Gelder & Schlatter(1927) 4)Vennin,Burlot & Lécorché (1932),568-70 5)Stettbacher(1933),345-55 and Figs 209,214,215, 216 & 217 6)Pepin Lehaleur(1935),366-71 7)Beyling & Drekopf(1936),150-239 8)W.H.Aughey et al,USP 2086527(1937) & CA **31**,6466(1937) 9)L.A.Burrows et al, USP's 2086530, -1, -2 & -3 (1937) & CA **31**,6466-7(1937) 10)L.A.Burrows et al, USP 2105635(1938) & CA **32**,2357(1938) 11)L.A.Burrows & S.L.Handforth, USP 2153171 (1939)(not found in CA) 12)W.Taylor,Chem & Ind **58**,1065-9(1939) 13)Davis(1943),413-24 & Fig 95 14)Meyer(1943)332-4 15)R.L.Grant, "Structural Features of Typical American Commercial Detonators", US BurMines RI No 3696(1943) 16)R.W.Lawrence, USP 2350172(1944) 17)Vivas,Feigenspan & Ladreda **4**(1945),297-321 17a)Pérez Ara(1945),655-63 18)P.E.Narvarte,USP 2377804(1945) 19)Stettbacher(1948),105-7 20)A.R.Ubbelohde,TrRoySoc **241A**,215 & 217(1948) 21)Olin Industries Inc, "Explosive Products",Bull (1950),25-38,736 & 741 22)Blasters' Hdb(1952), 92-9 23)Taylor(1952),10-11 24)Stettbacher, Pólvoras(1952),134-7 24a)Belgrano(1952),247-52, 25)PATR **2145**(1955),pp Rus 4-5(Conf) 25a)Cook (1958),16-17 26)Taylor & Gay(1958),52-67(17 refs) 27)PATR **2510**(1958),34-5 28)US Specifications on Blasting Caps: MIL-C-10592(Electric); MIL-C-11762(Electric and non-electric); MIL-C -20448(1)(Electric) 29)US Specs on Detonators: MIL-D-20503(Electric M1); MIL-D-20462A(Electric M36A1); JAN-D-409(Delay M1 & M2) 30)USSpec MIL-C-140003A(Caps, Blasting, Special) 31)Wm. H.Rinkenbach,Allentown,Pa; private communication (1962) 32)G.D.Clift,Chemical Center,Md; private communication(1962)

**Additional References on Blasting Cap Compositions**

In addn to the commonly-used chges mentioned under Blasting Caps(above), the following listing shows the variety of chges and modifications proposed by various investigators:

1)Westfälisch-Anhaltische Sprengstoff A-G, GerP 176719(1904) & CA **1**,1503(1907)(Priming compns contg Pb and Hg chromates as substitutes in whole or in part for $KClO_3$, with further addn of alk earth or heavy metal oxides, if desired) 2)K.W.Will,USP 827768(1906) & CA **1**,122(1907)(A priming compn: Tetryl 50 & MF 50%) 3)W.C.White,BritP 19983 (1906) & CA **1**,2518(1907)(A priming compn: MF 87.5 & AgF 12.5%) 4)L.Wöhler, GerP 196824(1907), BripP 4468(1908) & FrP 387640(1908); CA **2**,2302 (1908) & CA **3**,592,1690(1909)(Small quants of the heavy metal salts of hydrazoic acid are used as a substitute for MF as a primary chge for detonators and as an exploder, either alone or together with small amts of expl agent) 5)A.Lang,GerP 209812 (1908) & CA **3**,2228(1909)(A MF priming compn which does not produce rust, is obt by omitting an O carrier and adding Mg or Al powder melted with S in equiv amt. The proportion of MF to metal-S mixt varies from 1:1 to 2:1) 6)L.Wöhler, USP 904289(1909) & CA **3**,717(1909)(Superimposed layers of PA & LA are proposed for filling caps) 7)Stahl & Nölke, GerP 239162(1910) & CA **6**,2170 (1912)(A non-poisonous priming compn is prepd by mixing $P_4S_3$ with S and fusing or treating with a solvent) 8)H.Maxim,USP 988799(1911) & CA **5**, 2179(1911) [An expl compn for initiating HE's consists of Ca or Si 8.5 to 18, $Pb_3O_4$ 68 to 81 and a gelatinized mixt of NG/NC(70/30) 10 to 15%] 9)Eley Bros,BritP 2682(1911) & CA **6**,294(1912) (An initiating compn for use in detonators and the like, composed of MF, $BaO_2$ & TNT or known substitutes therefore; such addns being substituted in whole or in part for $KClO_3$, commonly employed)

10)W.Meyer,BritP 21337(1911) & BritP 23493(1911) & CA **7**,1100 & 1291(1913)[Manuf of initiating compns by employing $Ba(NO_3)_2$ with or without $PbO_2$, instead of the usual $KClO_3$. Eg: MF 25, $Ba(NO_3)_2$ 25, $PbO_2$ 35 & $Sb_2S_3$ 15%. An addn to the principle patent adds K picrate to increase expl power] 11)E.Goodwin,USP 1029287(1912) & CanP 147426(1913); CA **6**,2533(1912) & CA **7**, 2118(1913)(An initiating compn made of MF, a peroxide and TNT; said peroxide and TNT being substituted in whole or in part for $KClO_3$ commonly employed)(Compare with Ref 9) 12)R.Calvet,GerP 26323(1912),BritP 9597(1913), BritP 13501(1913) & SwissP 62590(1913); CA **7**, 4072(1913) & CA **8**,2254,3366,3860(1914)(A priming compn employing Cu perthiocyanate in admixt with $KClO_3$ or $KClO_4$) 13)W.H.Buell,USP 1027814 (1912) & CA **6**,1991(1912) (A priming mixt consistg of $Sb_2S_3$, $Pb(SCN)_2$, $KClO_3$ & TNT) 14)A.Jaques & G.Wells, BritP 23450(1912) & USP 1106147(1914); CA **8**,1347 & 3238(1914)(A priming compn contg dibenzoyl peroxide 40 & MF 60%. Another example is dibenzoyl peroxide, Pb or cuprammonium thiosulfate & $KClO_3$) 15)W.Meyer,BritP 25550(1912) & CA **8**,1509(1914)[Modification of earlier patent (Ref 10) by adding silicides to alk earths. Examples of priming compns: MF 20, $Ba(NO_3)_2$ 40, $PbO_2$ 10, $Sb_2S_3$ 20 & $Ca_2Si$ 10% or MF, $Ba(NO_3)_2$, K picrate, $Sb_2S_3$, $Ba_2Si$ & glass powd] 17)E.von Herz,BritP 27198(1912) & CA **8**,1672(1914)(One example of an initiating compn, employing Diazoperchlorate, consists of 1g PA and 0.02g Nitrodiazobenzene Perchlorate; the two chges being separated by a sheet of Cu foil or Sn; and the whole enclosed in Sn foil or perforated sheet Cu and varnished) 18)Sprengstoff A-G Carbonit,GerP 269826(1912) & CA **8**,2253(1914)(An expl, for primer & detonator caps or for filling projectiles, torpedoes or mines, is prepd from Hexanitrodiphenyl sulfide in $HNO_3$ by treating it with oxidg agents, to yield Hexanitrosulfobenzide) 19)C.F.von Girsewald, GerP 274522(1912) & CA **8**,3122(1914)(For the manuf of priming caps an ordinary No 8 Cu capsule is filled with ca 1g TNT & 0.05-0.1g Hexamethylenetriperoxidediamine and the mixt pressed. The Hexamethylenetriperoxidediamine is claimed to exceed by 4 to 5 times the expl power of MF) 20)Sprengstoff A-G Carbonit,GerP 286543(1912) & GerP 289374 (1913) & CA **10**,1272,2800(1916)(A filler for primers, primer caps and the like composed of compressed Hexanitrodiphenyl Sulfide(HNDPhSfi) 0.85g & MF 0.4g. It is claimed that HNDPhSfi is more powerful than either HNDPhA or PA and as the base chge is safer in caps than Tetryl)(Compare with Ref 26) 21)C.Claessen,GerP 288655(1913) & GerP 289446 (1914); CA **10**,2800 & 3162(1916)(Use of 1,2,3,4,6- or 1,2,3,5,6-Tetranitroanisole in primers is proposed) 22)H.C.Pritham,USP 1048207(1913) & CA **7**,703(1913)(A priming mixt contg $KClO_3$, MF & $Sb_2S_3$ bonded with Portland cement 2 to 4%) 23)M.P.Swope,USP 107394(1913) & CA **7**,3842 (1913)(A priming mixt consists of guncotton 20, amor P 5, $KClO_3$ 37.5 & $Sb_2S_3$ 37.5%) 24)C.Claessen,FrP 459979(1913), BritP 13086(1913) & SwedP 40379(1916); CA **8**,3238, 3860(1914) & CA **10**,1597 (1916)(A cap for use in mines and for military purposes, contains a chge of a nitrated compd, a chge of LA & a chge of MF or MF mixed with $KClO_3$) 25)C.Claessen,FrP 463714(1913) & Brit P 24839(1913); CA **8**,3238(1914) & **9**,1249(1915) (A secondary detonator for large quants of other expls, prepd by using Hexanitroethane, alone or mixed with other compds, such as TNT. The mixt of Hexanitroethane 45 & TNT 55% detonates with a very small quant of MF and can cause deton of other expls) 26)C.Hartmann,BritP 18354(1913) & CA **9**,381(1915)(HNDPhSfi in cryst uncompressed or compressed condition is proposed as a base chge in primers & detonators)(Compare with Ref 20) 27)Rheinisch-Westfälisch Sprengstoff A-G, GerP 277566(1913) & CA **9**,862(1915) [A priming compn, manufd from N sulfide in admixt with an oxidizing agent, such as $PbO_2$, $Ba(NO_3)_2$, $Pb(NO_3)_2$ or $KMnO_4$] 28)C.Claessen,GerP 284400(1913) & CA **10**, 970(1916)(Chges for mining & military initiators may consist of 0.85g Tetryl, 0.15g LA and 0.05g K picrate or of 0.85g Tetryl, 0.15g LA and 0.10g $KClO_3$ with 20% sugar) 29)A.Voight,USP 1095302(1914) & CA **8**,2253(1914) [A priming compn constg of Na nitrocresolsulfonate 25, $NaNO_3$ or $KNO_3$ 65 & $KClO_4$(or $KClO_3$)10%. Na nitrophenolate may also be used and an equal amt of TNT may be substituted for $KClO_4$ or $KClO_3$ in the above mixt] 30)W.H.Buell,BritP 21082(1914), USP 1174669(1916) & USP 1184316(1916); CA **10**, 970,1435 & 1791(1916) (A primer contg an azide with other substances. Eg; NC 3 & LA 1p; NC 11, LA 6 & Na azide 3ps and Na azide 35, $Sb_2S_3$ 35 & $KClO_3$ 30%) 31)E.von Herz,GerP 285902(1914) & CA **10**,970(1916) (A priming compn for small arms and other cartridges employs LSt alone or in combination with O carriers. For example, in a No 8 cap, 1g TNT, 0.2g LSt & 0.15g MF are separately compressed to form a detonator giving the same initiating action as 1g TNT & 0.555g MF) 32)L.Wöhler,USP 1128394(1915) & CA **9**,1118(1915) (A detonator for expl contg LA mixed with ca 3 times its wt of MF, with or w/o $KClO_3$. This mixt

cannot be "dead pressed" even at 2000atm press) 33)W. L.Main,USP 1147958(1915) & CA **9**,2592 (1915) (An initiating mixt composed of MF mixed with 5-70% $KBrO_3$ or other bromate. The bromate mixt gives a higher initiating force than a similar mixt contg chlorate) 34)W.Runge,USP 1168746 (1916), USP 1185830(1916) & CanP 181129(1917); CA **10**,822,2045(1916) & **12**,631(1918) (A primer compn is prepd by mixing LA with 5-30% by wt of TNT, with or w/o a very small amt of gum arabic as binder. This mixt gives more effective initiation than a mixt of LA & a chlorate) 35)R.Calvet,USP 1189238(1916) & CA **10**,2150(1916) [An initiating chge consists of Cu-perthiocyanate, $Cu(S_3C_2N_2)$ with ca 2.5-3 times its wt of $KClO_3$ or $KClO_4$. Stable, non-hygr detong chges of similar character may be made with $Cu(S_2C_2N_2)$, $Cu(S_3C_3N_3)_2$, $Pb(S_2C_2N_2)$, $Pb(S_3C_2N_2)$ or $Pb(S_3C_3N_3)_2$] 36)M.R.Swope,USP 1194095(1916) & CA **10**,2525 (1916) [An expl for charging primers or detonators consists of a mixt of NC 18, $KNO_3$ 4, $Ba(NO_3)_2$ 2.5, $Na_2CO_3$ 0.5, $KClO_3$ 50 & $Pb(SCN)_2$ 25%] 37)C.Claessen,SwedP 40749(1916) & CA **10**,2525 (1916) (A priming compn for caps consistg of a base chge of PETN with an initial chge of MF or of LA mixed with $KClO_3$) 38)A.J.Marin,USP 1206456(1917) & NorwP 29535(1919); CA **11**, 211(1917) & CA **14**,1441(1920) (A detong compd of the same action as fulminates, azides, etc consists of glycero-Pb chlorates or perchlorates, which can be produced by allowing glycerol or other multivalent alcs(such as mannitol, sugar, glucose, dextrin, etc) to act alone or with PbO on neutral or basic Pb chlorates or perchlorates) 39)O.Matter,USP 1239613(1917), CanP 176609 (1917) & CanP 176610(1917); CA **11**, 3438-9(1917) & **12**, 226(1918) [Caps chged with TNT, Tetryl, PETN or other nitro compds as a base chge and LA or a MF-$KClO_3$ mixt as a primary chge. See also USP 1254147(1918) & CA **12**,766(1918)] 40)Canadian Explosives Ltd,CanP 183497(1918) & CA **12**,1348(1918)(HNDPhSfi in cryst or compressed form is a compd suitable for use in caps, primers or detonators)(Compare with Ref 18) 41)C.J.S.Lundsgaard,DanP 23470(1918) & CA **13**, 1152(1919) [A priming compn composed of a mixt of $Ca(ClO_3)_2$, $Sb_2S_3$, powd glass with the addn of red P and a binder such as shellac, resin or rubber soln] 42)J.Harlé, USP 1306895(1919) & CA **13**,2283(1919) (PETN alone or mixed with nitrated benzene, toluene, phenols or amines is used as a base chge for detonators) 43)W.H.Buell,USP 1308393(1919) & USP 1312156(1919); CA **13**,2283 & 2599(1919) (Salts of TNR in priming compns. Eg: K or Ba TN-Resorcinate 15, Sn sulfide 35 & $KClO_3$ 50%) 44)C.M.Stine, USP 1309552(1919) & CanP 206311 (1920); CA **13**,2283(1919) & **15**,600(1921) [A blasting cap contg dinitroxylene dinitrate $[C_6H_2(CH_2NO_3)_2(NO_2)_2]$ and MF. These two compds may be mixed together in 80/20 proportions resp. Such a cap, when ignited by safety fuse or electrically, is an efficient detonator for dynamite or other HE] 45)W.H.Buell,USP 1311872(1919) & CA **13**,2599(1919) [A priming mixt made of Trinitrophenylnitramine, $[C_6H_2(NO_2)_3NH.NO_2]$ 15, $KClO_3$ 55 & $Sb_2S_3$ 30% or TNPhNA 10, $Pb(SCN)_2$-$KClO_3$ 50 & $Sb_2S_3$ 15ps] 46)C.M.Stine,USP 1313650(1919) & CanP 198328(1920); CA **13**,2763(1919) & **14**, 1609(1920) (A chge of nitrated hemicellulose together with TNT, PA & LA and a MF-$KClO_3$ mixt or other primary chge is suitable for detong dynamite) 47)A.S.Cushman,USP 1325928(1920) & CA **14**,633 (1920) [A priming mixt is made of $Sb_2S_3$ 20, $KClO_3$ 50, $Pb(SCN)_2$ 25, Tetryl 3-4 & PbO 1-2%] 48)W.G.Hudson,USP 1329525(1920) & CA **14**,1045 (1920) (An expl suitable for use as initiating chge is made of "colloided NC" 10-20 & LA 90-80%. The "colloided NC" may be NG 93-70 & NC 7-30%) 49)E. von Herz,BritP 142823(1920) & CA **14**,2859 (1920) (LSt alone, as an intermediate layer between TNT and MF, or in conjunction with other ingredients, is suitable for use in caps) 50)H.T.Peck, USP 1350465(1920) & CA **14**,3323(1920) (Diplumbic Dinitroresorcinate is used in priming mixts with ground glass, $Sb_2S_3$ & $KClO_3$) 51)Sprengluft-Ges, BritP 152335(1920) & CA **15**,756(1921) (A detonator chge consistg of paraffin, cork flour & LA and contained in a perforated rigid material casing, is impregnated with liquified gases; such a chge is used for detonating blasting cartridges similarly impregnated] 52)W.Eschbach,BritP 156429(1920) & CA **15**,1815(1921) [Priming compns are made by mixing LA, LSt or other expl compds in the presence of a phlegmatizing liq of low bp(such as benzene) in which a small quant of resin has been dissolved] 53)R.M.Cook & B.Grotta,USP 1385245(1921) & CA **15**,3751(1921) (A mixt of LA 40-95 & Tetryl 60-5% is used as a chge for blasting caps) 54)Peters Cartridge Co, BritP 165069 (1921) & CA **16**,648(1922) (A priming compn composed of Diplumbic-dinitroresorcinate mixed with ground glass, $Sb_2S_3$ & $KClO_3$)(Compare with Ref 50) 55)C.J.S.Lundsgaard & K.T.Herbst,BritP 168333(1921) & USP 1423233(1922); CA **16**,344 & 3399(1922) (Perchlorates of methylamines may be used alone or mixed with other expls for shells, mining expls or for intermediate chges

of detonators) 56)H.Rathsburg,BritP 177744 (1921) & CA **16**,3399(1922) (Cryst compds of mixed crysts & double salts contg the K salt of Dinitrodinitrosobenzene and difficultly sol salts of hydrazoic acid, Tetrazole derivs, etc are suitable for use in initiators) 57)H.Rathsburg,BritP 185,555 (1921) & CA **17**,1147(1923) (Expl salts of Tetrazole and Triazole or their derivs are used in detonators, percussion caps, etc. These salts may be mixed or pptd simultaneously to form double or mixed crysts with substances such as $NH_3$, nitrophenols, etc or may also be granulated with paraffin or resins dissolved in $C_6H_6$, $CCl_4$, etc) 58)E. von Herz,BritP 187012(1921) & USP 1498001(1924); CA **17**,1147 (1923) & **18**,2605(1925)(Mixts of LA & LSt for use as expl priming compns are prepd by simultaneously pptg the two salts) 59)H.Rathsburg,BritP 190215(1921) & USP 1470104(1923); CA **17**,3101 & 3920(1923) (A priming compn for loading blasting caps consists of the Pb salt of Trinitrophloroglucinol pptd simultaneously with other readily sol salts. For example, a mixt of the Na deriv of TNPhlGl, $NaN_3$ & the Na salt of Dinitrosobenzene may be pptd together. The blasting cap may also contain another substance as top chge) 60)W.Friederich,BritP 192830(1921) & CA **17**,3255 (1923) (Basic Pb Picrate and other basic Pb salts of highly nitrated org compds may be pptd simultaneously to form compns suitable for use in primers caps or detonators) 61)E.Ott,USP 1390378(1922) & CA **16**,344(1922) [Cyanuric Triazide, produced by interaction of cyanuric chloride & Na azide in aq soln, is suitable as a priming compn for expls. It can be poured while molten(mp 94°) directly into detonator caps; it does not form compds with metals used for casings; and its priming action is higher than that of MF or LA but its action is less brisant] 62)W.C.Cope,USP 1399104(1922) & CA **16**,833(1922) (An initiating compn adapted for ignition by flame or elec spark is made of MF 80, $Pb_3O_4$ 5-20 & $KClO_3$ 5-15%) 63)W.M.Dehn USP 1404687(1922) & CA **16**,1154(1922) (DADNPh is mixed with $KClO_3$ or other oxidizing salt to form an initiating compn) 64)H.T.Peck,USP 1407767 (1922) & CA **16**,1669(1922) (TNR, together with MF, ground glass, $KClO_3$ or other ingredients, is used for charging primers) 65)R.M.Cook & B. Grotta,USP 1406977(1922) & CA **16**,1669(1922) (HNDPhA together with primary detong compds such as MF & $KClO_3$, is used for charging caps) 66)H.Rathsburg & W.Friederich,BritP 195344 (1922) & CA **17**,3609(1923) (Basic salts of Tetrazole and its derivs are used singly or mixed together for use in primer & detonator compns) 67)T.Hawkins,USP 1398098(1922) & CA **16**,833 (1922) (PA 16, Pb oxide 48, & $KNO_3$ 2ps are mixed together with $H_2O$ and dried to form an expl suitable for use in detonators) 68)W. Friederich,USP 1424462(1922) & CA **16**,3399 (1922) (Detonating caps for mining or military purposes are formed with a main chge of LA superimposed with a chge of LSt) 69)A.Kowastch, CanP 222375(1922) & CA **16**,4067(1922) [A detonator for cartridges contains a carbonaceous substance(such as peat) satd with liq air, and mixed with LA] 70)H.Rathsburg,BritP 201009(1922) & CA **18**,472(1924) (Tetrazenes are used alone or in conjunction with other ingredients for primer compns. Eg: MF 30, $KClO_3$ 25, $Sb_2O_3$ 30 & Guanyldiazoguanyltetrazene 15%) 71)E. von Herz,BritP 207563(1922) & CA **18**,1573(1924) (Caps are loaded with one or more of the o- or p-nitrated quinone diazides of polymeric phenols or their metallic salts. These compds are used either as a top chge over a base chge such as Tetryl, TNT or PETN, or in admixt with the usual compn components) 72)J.E.Burns,USP 1437224(1923) & CA **17**,635(1923) (A priming mixt is made of $KClO_3$, 30, $Pb(NO_3)_2$ 12, $Pb(SCN)_2$ 33 & powd glass 25%) 73)B.Grotta,USP 1439099 (1923) & USP 1456341(1923); CA**17**,883 & 2506 (1923) (An initiating mixt which does not readily become dead-pressed and is not readily affected by moisture consists of $HgN_3$ 20, MF 60 & $KClO_3$ 20%. As a base chge an equal wt of tetryl or other HE can be used) 74)W.O.Snelling,USP 1462074 (1923) & CA **17**,3101(1923) (Detonators are formed with an initial priming chge of MF and a main chge contg NS, $KClO_3$ & DPhA) 75)C.E.Waller,USP 1462093(1923) & CA **17**,3101(1923) (Primer compns are formed of NS in granules of av size in excess of 0.045mm, together with $KClO_3$ & DPhA) 76)Etablissements Davey,Bickford,Smith et Cie, BritP 196593(1923) & CA **17**,3791(1923) (LA for use in primers is desensitized by the addn of 0.05 -20% by wt of oils, greases or paraffins) 77)E.I. duPont & Co,BritP 204646(1923) & CA **18**,905(1924) [PETN in priming compns for igniting proplnt expls Eg: PETN 5-10, $KClO_3$ 50, $Pb(SCN)_2$ 25-23 & $Sb_2S_3$ 20-17%; or PETN, $KClO_3$, MF & $Sb_2S_3$] 78)B.Grotta,USP 14836(1924) & CA **18**,905(1924) (A base chge of detonators is made of ground, smokeless proplnt mixed with Tetryl, TNX or similar aromatic nitro compds) 79)E.von Herz, BritP 241,892(1924) & USP 1625966(1927); CA **20**, 3574(1926) & **21**,2065(1927) (Salts of isonitramines, for use such as Pb methylenediisonitramine in detonator compositions and other ingredients may

be pptd simultaneously with them) 80)C.I.B. Henning,USP 1473818(1924) & CA **18**,472(1924) (HNDPhA, when used with $KClO_3$, $Sb_2S_3$ & $Pb(SCN)_2$, is suitable for use in primers which ignite w/o deton when lightly struck) 81)W. Friederich,USP 1478429(1924) & CA **18**,905(1924) [Basic Pb Hexanitrodinitroresorcinate, $C_6(NO_2)_3O_2(Pb.OH)_4$, or other cryst basic or double salts are used with the usual ingredients for prepg priming mixts for expls] 82)E.M.Symmes,USP 1480795 (1924) & CA **18**,905(1924)(TNB is used, together with various other ingredients, in initiating compns) 83)E.Harlé,USP 1488787(1924) & CA **18**,1911(1924) [LA, mixed with 0.05-20% of fatty or similar substance(12-14% paraffin), forms a desensitized priming compn which retains its power undiminished] (Compare with Ref 76) 84)J.M.Olin,USP 1495350 (1924) & CA **18**,2252(1924) (Ferro-Si with MF & $KClO_3$ in priming compns) 85)J.B.Smith,USP 1502754(1924) & CA **18**,2964(1924) (A detonator or blasting cap contains as a base chge, PA mixed with TNT. MF is used as a primary chge) 86)C.I. B.Henning,USP 1503530(1924) & CA **18**,2964(1924)[A mixt which is easily detonated is comprised of TNB, $KClO_3$, MF or $Pb(SCN)_2$ & $Sb_2S_3$] 87)H.Rathsburg, USP 1511771(1925) & USP 1580572 (1926); CA **19**,178(1925) & **20**,1907(1926) (Same as Ref 57) 88)C.A.Woodbury, USP 1518629(1925) & CA **19**,578(1925) [Blasting detonators are made with a base chge of ground pyro-NC (100% thru 30 -mesh sieve and 35-90% thru a 100 mesh sieve) and a primary detong chge of MF & $KClO_3$] 89)B.Grotta, CanP 246338(1925) & CA **19**,1349(1925)(A compn for detonator contains MF, $HgN_3$ & TNT) 90)B. Grotta,USP 1533798(1925) & CA **19**,1778(1925)(The base chge for a compd detonator consists of a mixt of equal amts of Tetryl & $NH_4ClO_4$ or $KClO_3$, while the primary chge is of MF & a heavy betal azide) 91)W.Friederich,USP 1552836(1925) & CA **19**,3596 (1925) [A priming mixt suitable for general use with expls is prepd by pouring solns such as of $NaN_3$ & Na picrate into solns such as of $Pb(NO_3)_2$] 92)H.Rathsbrug,USP 1588277(1926) & CA **20**,2751 (1926) (Tetracene is used with chlorates, nitrates, peroxides, etc to form an expl primer compn) 93)Remington Arms Co, BritP 285232(1927) & CA **22**,4821(1928) (A priming mixt w/o perchlorate is made with MF, $Ba(NO_3)_2$, $Pb(SCN)_2$ & $Sb_2S_3$) 94)Nobel's Explosives Co Ltd & G.Morris,BritP 297853(1927) & CA **23**, 2827(1929) [Detonators for blasting purposes are provided with a high d base chge of PETN or a mixt of Tetryl & TNT (loaded in molten condition) and a priming chge of LA & LSt] 95)A.W.Schorger,USP 1681259(1928) & CA **22**,3780(1928) [A solid defgrg oxide of C ("graphitic oxide") is mixed with MF,TNT,PA, etc to obt a primary mixt for expls] 96)O.Turek, BritP 308781(1928), GerP 494289(1928) & USP 1824848(1932); CA **24**,502,2886(1930 & **26**,309 (1932) [A detonator contains a base chge of highly compressed TATNB(Triazidotrinitrobenzene), TNT or Tetryl and a top chge of TATNB loaded at a press not exceeding 300kg/cm$^2$). LA may be used together with TATNB as the top chge] 97)Werkzeugmaschinenfabrik Oerlikon,BritP 309114(1928) & CA **24**,502(1930) (Primers are formed with a primary chge of $KClO_3$ & $Sb_2S_3$ with or w/o MF, a secondary chge of LA, and a tertiary chge of TNT, Tetryl or PETN) 98) H.Rathsburg & E.von Herz,BritP 310509(1928) & GerP 518885(1928); CA **24**, 728(1930) & **25**, 3487(1931) [Mixt of LSt & Tetracene with or w/o $Ba(NO_3)_2$, $Sb_2S_3$ or silicides is proposed as a primary compn. Another example: LSt 25-55, $Ba(NO_3)_2$ 24-25, $PbO_2$ 5-10, Tetracene 0.5 -5, $Sb_2S_3$ 0.10, $CaSi_2$ 3-15 & glass powd 0/5%] 99)E.M.Symmes,BritP 333534(1928) & CA **25**, 595(1931) (DADNPh is mixed with LA as a primary chge above a base chge of Tetryl, TNT or PA) 100)K.F.Paul,BritP 333539(1928) & CA **25**,595(1931) (DADNPh is used in blasting detonators with or w/o $KClO_4$, $KClO_3$ or $NH_4ClO_4$ as oxidg agents in either the top or base chge. Other compds such as Tetryl, TNT or PA may be used as base chges with DADNPh as top chge) 101)J.Piccard,BritP 340971(1928) & CA **27**,2303 (1933) (DADNPh may be used in admixt with 20 -80% of Tetryl, TNA, TNT or MF as a chge of blasting caps) 102)J.D.McNutt,USP 1718370 (1929) & USP 1755330(1930); CA **23**,4074(1929) & CA **24**,2886(1930). (A non-corrosive priming compn is made of MF, $BaO_2$ & Ca silicide or MF, $Ba(NO_3)_2$ & DPhA) 103)Hercules Powder Co, FrP 675638 (1929) & FrP 676933(1929); CA **24**,2886 & 3115 (1930)(A priming chge for blasting caps contains DADNPh 20-80 & LA 80-20%. This mixt may be used above a chge of TNT or PA) 104)W.Eschbach & W.Friederich,BritP 343485(1929) & GerP 605840 (1934); CA **27**, 2303 (1933) & **29**, 1988(1935)[Mixt of PETN(phlegmatized with paraffin, stearin or beeswax) and NC(gelatinized with NG, NGc, Nitropolyglycerinol or the like) is compressed at ca 800kg/cm$^2$ to form a chge for detong caps] 105)E.I.duPont,GerP 564584(1930), BritP 350036 (1929); CA **27**,1177 & 2304(1933) [An expl filler for elec detonators contains MF or LA and a mixt of $Pb(SCN)_2$ 30-50, $KClO_3$ 10-30 & smokeless proplnt 30-50%, as ignition chge] 106)W.deC.

Crater,USP 1759565(1930) & USP 1887290(1933); CA **24**,3649(1930) & **27**,1513(1933) (A blasting cap chge is composed of cryst Nitrolactose as a base chge with MF & $KClO_3$, LA or DADNPh as primary chge) 107)E.von Herz,FrP 683345(1929) & USP 1878652(1933); CA **24**,4636(1930) & **27**,420(1933) [An intermediate chge for detonators may be made of HNMnt or of its mixt with PETN (in mol proportions) and an ignition mixt of Mg & Al with oxidg substances which may contain metallic(such as Pb) hypophosphite] 108)J.D.McNutt,USP 1774992 (1930) & CA **24**,5160(1930) (An expl priming mixt comprised of $PbO_2$, Ba chromate, MF & Tetryl) 109)D.T.Jones et al, BritP 328277(1930) & CA **24**,5499) (1930) [Caps chged with one or more basic normal or acid salts of 2-mononitroresorcinol which may be used with LSt, and to this may be added] $Ba(NO_3)$ or PETN] 110)J.D.McNutt,USP 1779820(1931),USP 1779821(1931), USP 1779851 (1931), USP 180023(1931) & USP 1825466(1932); CA **25**,208,3487,5564 & **26**,309(1932) [Priming mixts are composed of the following ingredients: $PbO_2$ 20-40, $Ba(NO_3)_2$ 3-10, MF 30-45 & PETN 3-15%; $Ba(NO_3)_2$ >40, MF ca 35, $Pb(SCN)_2$ ca 16, $BaCO_3$ 2 & charcoal 2%; MF(contg 16% $H_2O$) 475, $Ba(NO_3)_2$ 240, $Sb_2S_3$ 255, TNT 30 & DPhA 0.5-2p; or basic Pb nitrate, MF, $Pb(SCN)_2$ gum arabic & ground glass] 111)Zündhütchen- und Patronenfabrik vorm Sellier & Bellot und Frantisek Bletcha, Austrian P 126150(1931) & CA **26**,2320 (1932) [An initiating compn consists of a colloidal ppt of $AgN_3$ or $HgN_3$ which is mixed while moist with substances such that the mixt can be granulated and dried. Additives may include kieselguhr, asbestos, $KNO_3$, $Ba(NO_3)_2$, $KClO_3$, PA, MF or $Sb_2S_5$] 112)P.R.Aaronson, USP 1826714(1932) & CA **26**,601(1932) [ A priming mixt for expls consists of MF, $Ba(NO_3)_2$ & Cd peroxide] 113)J.D. McNutt, USP 1842556(1932) & CanP 319719(1932)) (A priming mixt consistg of $PbO_2$ 20-40, Ba chromate 5-10, MF 25-40 & TeNA 3-15% or MF 40, $Ba(NO_3)_2$ 29, $Pb(SCN)_2$ 10 & an abrasive 20%) 114)A.S. O'Neil & A. G.Schuricht, USP 1849355(1932) & CA **26**,2867(1932) (An expl contg NC & TeNA in colloidal form, can employ a cap contg TeNA, or TNT as a base chge and MF as priming chge) 115)J.D.McNutt,USP 1851398(1932) & CA **26**, 3114 (1932) [An expl priming mixt contains MF 45, basic Pb nitrate 8, $Ba(NO_3)_2$ 30, $Sb_2S_3$ 5, Ca silicide 4 & $Pb(SCN)_2$ 8%] 116)E.von Herz, USP 1859225(1932) & CA **26**,3923(1932) [LSt is used with Ca silicide or MF, $PbO_2$ & $Ba(NO_3)_2$ as a priming chge] 117)J.E.Burns, USP 1862295(1932) USP 1900157 (1933) & USP 1905795 (1933); CA **26**,4177(1932) & CA **27**,3080,3612(1933) [Tetracene with DADNPh, $Pb(NO_3)_2$, $Pb(SCN)_2$, LSt & glass is used as a priming compn](Compare with Ref 92) (See also USP 1991731(1935) & CA **29**,2360(1935) and USP 2038097(1936) & CA **30**,4010(1936)] 118)J.E.Burns,USP 187862(1933) & CA **27**,420 (1933) [2,6-Dinitroquinone-2-diazide is used with Pb picrate, $Pb(NO_3)_2$, $Pb(SCN)_2$, gum arabic & glass as a priming chge] 119)L.H.Fisher, USP 1890112(1933) & CA **27**,1758(1933) (An igniter chge for blasting caps is composed of $K_3FeC_6N_6$ 20-40, $KClO_3$ 10-30 & NC 70-30%) 120)J.D.McNutt, USP 1906394(1933), USP 1930653(1934) & USP 2002960(1935); CA **28**,328(1934) & **29**,4944(1935) [Pb dinitrophenylazide is used with $Ba(NO_3)_2$ and various other additives to form an expl priming compn. It is also used with Ag Tetracene, with $PbO_2$, $Ba(NO_3)_2$, gum & $Sb_2S_3$, and with LSt plus other ingredients] [See also USP 2005197(1935) & CA **29**,5274(1935)] 121)G.A.Noddin,USP 1906869 (1933) & CA **27**,3612(1933) [An elec blasting cap is primed with LA covered with a layer of loose mixt of $Pb(SCN)_2$, $KClO_3$ & ground pyro-NC] 122)H.A.Lewis, USP 1918920(1933) & CA **27**, 4931(1933)[A blasting cap contains TNT as a base chge, LA as a primary chge and a top layer of $Pb(SCN)_2$, $KClO_3$ & ground pyro-NC] 123)S.B. Large, USP 1928204,5,6 & 7(1934) & CanP 341781(1934); CA **28**,328 & 5242(1934) (Compd detonators for expls consist of the following chges: a primary chge of HNMnt & a base chge of Tetryl; a primary chge of HNMnt with a fuse head of $KClO_3$ & MF; a primary chge of HNMnt & nitrolactose; or a primary chge of Nitrolactose alone) 124)J.E.Burns, USP 1928780(1933) & CA **27**,598 (1933) (Pb salt of dinitrosalicylic acid is used, with MF or other additives, as a priming chge) 125)J.Meissner, USP 1930765(1933) & CA **28**,328 (1934) (Chges for detonators consist of LA as primary and TNT as base chge) 126)M.F.Biazzi, BritP 387545(1933) & USP 1950019(1934); CA**28**, 328 & 3235(1934) [Blasting detonators comprising a base charge(such as an aromatic nitrocompd) separately compressed in an Al case, surmounted with a primary chge compressed in a small cap either of Cu(if MF is used) or of Al(if LA is used)] 127)W.deC.Crater,USP 1951595(1934) & CA **28**, 3590(1934) (Inositol nitrate as a chge in blasting caps) 128)J.Piccard,USP 1964077(1934) & CA **28**,5242(1934) (A flash compn for use in blasting caps is formed of dimethylpyrone methyl perchlorate, $KClO_3$ & $AgNO_3$, with an NC binder added) 129)H.A.Lewis,CanP 340569(1934) & USP 1964825 (1934); CA **28**,4235 & 5242(1934) [An ignition

compn, as the top chge in a blasting cap, contains $Pb(SCN)_2$ 30-70, $KClO_3$ 30-60 & S 1-20%; the primary chge is LA]
130)A.Weale,USP 1969246(1934) & CA **28**,6313 (1934) [A priming compn for expls is made of $PbO_2$ with a small proportion(1-5%) of a catalyst such as $MnO_2$, $V_2O_5$, $Mo_2O_3$, Na tungstate or their mixts] 131)W.Brün, USP 1971029, -30 & -31(1934) & USP 1991730(1935); CA **28**,6314(1934) & **29**,2360(1935) (Compds suitable for use in priming compns are the basic Pb salt of 3,5-DNBAc, the basic Pb salt of 3-nitrophthalic acid, and Pb dinitrobenzoate nitroate or the nitroic Pb salt of TNBAc. The basic Pb salt of 2,4-DNBAc may be used together with MF, $Ba(NO_3)_2$ & an abrasive) 132)W.Eschbach & W.Friederich,BritP 417763(1934) & CA **29**,2744 (1935) (A detonator, free from MF, is of Al, Cu, brass or Zn casing contg a base chge of PETN or other usual chge and a priming chge of a mixt of LSt or dibasic picrate with 10-20% of Hg, Ag and/or Cu azide added in aq suspension) 133)A. Weale, CanP 348291(1935) & CA **29**,3518(1935) [A non-corrosive priming chge is comprised of MF 20-45, KBa nitrate(double salt) 30-60 & $Pb(SCN)_2$ 10-40%] 134)P.G.Wrightsman,USP 1975186 (1934) & CanP 348643(1935); CA**28**,, 7536(1934) & **29**, 3518(1935) (A cast expl suitable as a base chge for blasting caps is made of a fused mixt of Trinitrophenylethylnitramine (TNPhEtNA) and either Tetryl or PETN or both. One example contains TNPhEtNA 40, Tetryl 40 & PETN 20%) 135)C.P.Spaeth, USP 1984846(1935) & CA **29**,1251 (1935)(Tetramethylene diperoxide dicarbamide, alone or with various admixts, as an ignition top chge for elec detonators) 136)H.A.Lewis,USP 1991857(1935) & CA **29**,2360(1935) (A blasting cap of Al contains LA placed nearest to the closed end of the tube and a secondary chge of Tetryl) 137)ICI, FrP 781646(1935) & FrP 796833(1936); CA **29**,6430(1935) & **30**,6200(1936) (A compn which is ignited directly by an elec current is comprised of a mixt of Zr powd 70 & Pb mononitroresorcinate 30% in a sufficient amt of a 5% soln of NC in amyl acetate to make a creamy paste) 138)C.E.Sosson & ICI, BritP 428872(1935) & USP 2027208(1936); CA **29**,7078(1935) & **30**,1564(1936) (An ignition compn for low tension elec blasting fuses is made of finely divided Zr 35-39 & the basic Pb salt of 2-mononitroresorcinol 65-61%; the mixt may be used loose or agglomerated with an NC cement. For use in delay detonators a mixt of Zr 50-95 & the Pb salt 50-5% is used) (Compare with Ref 137) 139)G.H. Chambers,GerP614712(1935) & CA **29**, 8335(1935) [A priming compn contains Zr powd 10, $Ba(NO_3)_2$ 40, MF 25 & $Sb_2S_3$ 25%] 140)J.D.McNutt, BritP 432096(1935) & CA **30**,618(1936) (Alkali or alkaline earth salts of dinitrophenyl azide are used in priming compns) 141)J.D.McNutt,USP 2004505 (1935) & USP 2009556(1935); CA **29**,5274 & 6430 (1935) (Tetracene & LA are used together or with various other substs such as $PbO_2$, $Sb_2S_3$, $Ba(NO_3)_2$, Ca silicide or DADNPh) (Compare with Ref 117) 142)W.Brün,USP 2004719(1935) & CA **29**,5274(1935) [About 1-5% of the $CuNH_4$ salt of diazoaminotetrazole is used with an initiating mixt of LSt 30-50, $Pb(NO_3)_2$ 25-40, $Pb(SCN)_2$ 5-15 & an abrasive 10-20% to form a priming compn] 143)C.P.Spaeth, USP 2007223(1935); CanP 353339(1935) & USP 2031677(1936); CA **29**,56608336(1935) & **30**,2388 (1936) (An ignition compn for the top chge in blasting caps contains NC impregnated with NG & $KClO_3$. The base chge consists of smokeless propInt 40-80, NG 3-35 & $KClO_3$ 2-25%) 144)G.H. Jacobs,USP 2027825(1936) & CA **30**,1564(1936) [About 2-30% of Zr powd is used with $Ba(NO_3)_2$, Pb chromate, $Pb(SCN)_2$, MF & ground glass as a priming mixt] 145)E.I.duPont,BritP 451668 (1936) & CA **31**,542(1937) [Blasting detonators are made of Al or high Al alloy and are charged with $Pb(SCN)_2$ 50, $KClO_3$ 40 & S 10%] 146)W.O. Snelling,USP 2067213(1937) & CA **31**,1616(1937) (Finely divided MF or LA is mixed with natural or synthetic rubber or rubber substitute as an expl suitable for detonators) 147)L.Rubenstein & ICI, BritP 473146(1937) & CA **32**,1934(1938) [Low tension elec blasting detonators contain a primary initiating chge and a superimposed loose defgrg compn. The defgrg compn is made by corning 90ps of basic Pb salt of 3,5-dinitro-2-hydroxytoluene (contg 58% Pb) with 10ps $KClO_3$ with the aid of 1-2ps acacia gum in 60ps $H_2O$; the primary chge consists of 1g of 80/20 MF/$KClO_3$ mixt] 148)Soc-d'Exploitation des Brevets O.Matter,FrP 818285 (1937) & CA **32**,2358(1938) (A priming compn contains MF 65, $Ba(NO_3)_2$ 22, $Sb_2S_3$ 11, RDX 15.5 & $BaCO_3$ 1.5g) 149)L.Rubenstein & ICI,BritP 470418 (1937) & USP 2125462(1938); CA **32**,1456 & 7728(1938) (A blasting cap contains a base chge of Guanylazide picrate with or w/o other base chge expls such as Tetryl and a primary chge of LA, with or w/o LSt. The detonator case shall be of Al and have an elec fusehead primed with Pb mononitroresorcinate. Alternatively, the primary chge may be MF and the detonator case of Cu or Cu alloy) 150)L.H.Fisher, USP 2104513(1938) & CA **32**,1935(1938) [An initiating expl for blasting cap consists of DADNPh & $Ba(NO_3)_2$] 151)P.W. Schuster,GerP 655318(1938) & CA **32**,2754(1938)

[A blasting cap contg a self-igniting chge composed of $KClO_3$ & a soln of yel P in $CS_2$. The chge ignites when the solv($CS_2$) is evapd at a controlled rate] 152)Deutsche Waffen-und Munitionsfabriken A-G,FrP 824130(1938) & CA **32**,5630(1938) (A priming compn, resistant to oxidn, contains LSt 30-60, Diazotriazolecarboxylic acid 1-10% together with $Sb_2S_3$, $PbO_2$, $Ba(NO_3)_2$ & CaSi) 153)L.A. Burrows et al USP 2105635(1938) & CA **32**,2358 (1938) (An ignition compn suitable for use in elec blasting caps uses Bis-triethyl Pb styphnate) 154)W.F.Filbert & W.E.Lawson,USP 2118501(1938) & CA **32**,5630(1938) (Pb salt of the nitrated prod of diphenylol propane with $KClO_3$ or with Zr & NS is proposed as an ignition compn for elec blasting caps) 155)C.A.Woodbury,USP 2118533 (1938) & CA **32**,5632(1938) (Blasting caps contg a homogeneous blend of BkPdr & ground smokeless proplnt) 156)R.F.B.Cox,USP 2125221(1938) & CA **32**,7728(1938) (Hexanitrodiphenylethylenedinitramine as a chge in blasting caps) 157)V.J. Kelson,AustralianP 104189(1938) & CA **32**,8782 (1938) (A primer mixt consists of MF, K dinitrophenylazide, KBa nitrate double salt, $Sb_2S_3$ & Pb hypophosphite) 158)J.D.McNutt,BritP 495238 (1938),USP 213680(1939) & USP 2292956(1943);CA **33**, 1500,3158(1939) & **37**,1042(1943)(A priming mixt suitable to ignite a proplnt is comprised of MF,K dinitrophenylazide,KBa nitrate double salt,$Sb_2S_3$ & Pb hypophosphite) (Compare with Ref 157) 159)Wm. H.Rinkenbach & H.Q.Aaronson,USP 2167679(1939) & CA **33**,8992(1939) (Dinitroethylurea is used alone or with other materials in blasting caps or as the booster chge) 160)Dynamit A-G, BritP 510992(1939) & CA **34**,5664(1940) (An all-purpose priming compn is made by causing salts of Tetrazylazide to react with chlorides, sulfates or nitro compds or org substances in soln. The usual priming consituents may be admixed with the product) 161)L.A.Burrows & W.F.Filbert,USP 2175249(1940) & CA **34**,888 (1940) (An ignition chge in the form of a bead surrounding the bridge wire for an elec blasting initiator of the delay type is made of a complex Pb nitrate salt & bis basic Pb picrate) 162)W.Brün, USP 2175826(1940) & CA **34**,887(1940) [An expl priming compn is prepd by moistening(w/o dissolving) a mixt of Pb or Ca nitrate with a hypophosphite of K, Na, Ca, Sr, $NH_4$, Ba or Mn] 163)E.B.W. Kerone & C. C.Carroll,USP 2177657(1940) & CA **34**,1176(1940) [Basic Pb nitroresorcinol salt with MF or LA, $Ba(NO_3)_2$ & other ingredients is used in primers] 164)H.E.Nash,USP 2186426 & 7(1940) & CA **34**,3498(1940) (An elec blasting cap contains a detong chge and an igniter chge comprised of DADNPh & $KClO_3$ or of DADNPh & NC or NS) 165)G.H.Smith & C.B.van Winter,USP 2189301(1940) & CA **34**,4271(1940) (An elec blasting initiator is comprised of ground smokeless proplnt with S, Ca silicide, Zr or Se and $KClO_3$, $BaO_2$ or $KNO_3$) 166)H.I.Etchells,Jr,USP 2190777(1940) & Ca **34**, 4272(1940) (DADNPh is used with $Ba(NO_3)_2$ & a nitrated carbohydrate or smokeless proplnt as an ignition compn in elec blasting caps) 167)C.E. Pritham et al, USP 2194480(1940) & CA 4908(1940) (A non-corrosive priming mixt for expls is made of red P, $Ba(NO_3)_2$ & $Sb_2S_3$) 168)S.B.Large & G.F. Rolland,USP 2195032(1940) (A detonator contg a base chge of Tetryl, a primary chge of the "safety" type expl and an ignition chge of not more than 0.15g DADNPh. The ignition medium serves to inflame the primary chge but is incapable of directly detong Tetryl) 169)W.B.Woodring, USP 2206652 (1940) & CA **34**,7610(1940) (A priming expl compn is made of LSt, the Pb, Na or Cd salt of Trinitrosophloroglucinol & an oxidg agent) 170)P.Naoúm, GerP 698403(1940) & CA **35**,6796(1941)(A detonator is charged with Hexamethylenetriperoxidediamine alone or in admixt with inert substances) 171)E.I. duPont,BritP 519749(1940) & CA **36**,274(1942) [An ignition compn for elec blasting detonators consists of or includes a complex or double salt of $Pb(NO_3)_2$ & a Pb salt of nitrophenol] 172)W.deC. Crater,USP 2214721(1941) & CA **35**,898(1941) (A base chge of PETN with a superimposed priming chge of DADNPh is used in blasting caps) 173)W.Brün,USP 2239547(1941) & CA **35**,4956 (1941)(A method for prepg priming mixts involves mixing $Ba(NO_3)_2$, glass pdr, moist Styphnic Acid & moist basic LSt; the mixt is maintained in moist condition so that normal LSt is formed by reaction of moist styphnic acid and basic LSt) 174)R.W.Lawrence,CanP 398139(1941) CanP 398865(1941),BritP 546276(1942) & USP 2350172(1944); CA **35**,6796 & 7716(1941) & **37**, 3274(1943) (An elec blasting cap resistant to deton by external heat contains a priming chge of LA & a secondary chge of PETN, 30-60% by wt of the priming chge. In a later device, a protector unit, at least 0.01" thick, of TNT or p-nitrobiphenyl is placed between the metal casing and the detong expl to desensitize the chge to external heat) 175)E.von Herz et al,GerP 708238(1941) & CA **37**,2938(1943) (A priming compn, sensitive to flame, impact or friction, is made of a mixt of a nitrate, a tetra-, penta- or hexahydric alcohol, Tetracene & a powd metal of good thermal conductivity) 176)L.A.Burrows & G.A.Noddin, USP 2268372 (1942) & CA **36**,2726(1942) (In an ignition compn

for elec blasting caps, use is made of a loose chge of colloided smokeless proplnt & ca 15-25% of Pb 4,6-dinitro-o-cresol) 177)F.M.Garfield,USP 2295104(1943) & CA **37**,1272(1943) (Cryst double salts of normal LSt & Pb acetate or Pb propionate are proposed for use in blasting cap ignition or priming charges) 178)L.A.Burrows,CanP411441 (1943), CanP 411756(1943) & USP 2427899(1947); CA **37**,3607 & 3943(1943) & **42**,764(1948) (A blasting initiator contains a base chge of HNMnt and a top chge of DADNPh & $KClO_3$; part of the top chge is disposed in a cavity in the base chge. A later device contains a detong expl base chge, a LA primer chge and an ignition chge of Tetryl 30-70 & LSt 70-30%; dead-pressed HNMnt is placed between the ignition and primer chges) 179)SFMCTG,FrP 881262(1943) & CA **47**,8374(1953) [Guncotton mixed with $PbO_2$ (60%), $Pb_3O_4$(65%) or $KMnO_4$ (50%) produces compns suitable for use in igniters of elec primers. Changes in sensitivity or ignition props can be obtd by adding $Sb_2S_3$ or C & $KClO_3$ or $KClO_4$] 180)SFMCTG,FrP 893941(1944) & CA **47**,8374(1953) (Mixts of usual priming agents with expls to increase the vel of deton are described. Typical compns are: Trinitroazobenzene, PA & Urea Picrate or Tricycloacetone peroxide, PA & RDX. A still higher vel of deton is achieved by using a plastic tube of NC & BkPdr to replace tubes made of Cu or brass) 181)L.R.V.Clark, USP 2326008(1944) & CanP 435873(1946); CA **38**,488(1944) & **40**,6818 (1946) (An initiating chge of Pb nitroaminoguanidine is superimposed upon a base chge of PETN as a fuse or blasting cap compn) 182)G.M.Calhoun,USP 2327867(1944) & CA **38**,867(1944) [Ammunition priming compns are made of Pb hypophosphite 8-10, $Pb(NO_3)_2$ 10-12, LSt 28-33, $Ba(NO_3)_2$ 14-23.5, glass 30 & LSt 0.5-2%] 183)W.Brün,USP 2341205(1944) & CA **38**,4448(1944) (Mixts of Tetracene, LSt & PA are used in various priming compns) 184)W.Brün & L.A.Burrows,USP 2341263(1944) & CA **38**,4448 (1944) [Ammunition priming mixts are made of MF, $Ba(NO_3)_2$ & Hexamethylenetriperoxydiamine (as sensitizer) 0.5-10%; other ingredients may be added] 185)P.H.Burdett & G.M.Calhoun,USP 2345868(1944) & USP 2350670(1944); CA **38**, 4806 & 5086(1944) [An ignition priming mixt is prepd from normal Pb 3.5-dinitrobenzoate 8, LSt 40, Tetracene 2, $Pb(NO_3)_2$ 30 & glass pdr 20%. Also the acid Pb salt of DNR (1-15%) is used together with the same materials] 186)J.D.McNutt & S.D.Ehrlich,USP 2352964(1944) & CA **38**,6098 (1944) (A complex salt suitable for use in detonators or primers is made of equimolecular proportions of Pb hypophosphite & basic and normal LSt in aq soln at 70°) (Compare with Ref 158) 187)George A.Lyte,USP 2360698(1944) & CA **39**,1294(1945) (A blasting cap is filled with 3 separate charges: initiating chge – <0.10g LA; secondary chge – 0.25–0.35g of LA & TNT; and main chge–PETN & TNT) 188)E.J.Hanley,USP 2363863(1944) & CA **39**,3672(1945) (An initiating expl for secondary expls is comprised of LA 60-95 & BkPdr or smokeless proplnt 5-40%) 189)L.A.Burrows,CanP 428518(1945) & CA **39**,5080(1945) (A blasting cap contains a base chge of PETN and a top chge of DADNPh & $KClO_3$; at least part of the top chge is disposed in a cavity in the base chge) 190)G.F. Rolland,USP 2388368(1945) & CA **40**,1036(1946) (An ignition compn contg cuprous acetylide or other metallic acetylide, is prolonged in sensitivity life by incorporating up to 5% of abietic acid or rosin) 191)E.I.duPont & L.A.Burrows,BritP 568109(1945) & CA **41**,2900(1947) (An initiating compn is produced by mixing crysts of DADNPh & HNMnt with a solv miscible with w but in which HNMnt is sol and DADNPh is insol) 192)L.A.Burrows,USP 2396152(1946) & CA **40**, 3606(1946) (An initiating expl compn for loading blasting caps consists of a base chge of PETN and a priming chge of DADNPh & HNMnt. When unconfined, this priming chge burns w/o expldg) 193)G.U.Graff,USP 2395045(1946) & CA **40**,3608 (1946) (A priming compn for initiating LA is prepd from a mixt of $PbO_2$, Ca silicide, Zr & S; $MnO_2$ can be used to replace part of the $PbO_2$) 194)W.M.Cobb,USP 2400103(1946) & CA **40**,4525(1946) (A substantially spherical blasting cap contg a base chge such as Tetryl, PA, PETN or TNT will deton consistently if heat is applied by thermite, composed of Mg powd or $BaO_2$ & an oxidg agent. Thus, the usual extremely sensitive priming chge is eliminated) 195)L.A.Burrows & W.E.Lawson,USP 2402235 (1946) & CA **40**,5568(1946)[Blasting caps are made less sensitive to shock & frictional impact by blending with the primary chge a small quant(0.5 -3%) of Ca stearate in finely divided condition] 196)W.W.Vogl,USP 2406573(1946) & CA **41**,286 (1947) (An expl suitable for loading detonators, fuses, boosters or shells is prepd from ethylenediamine perchlorate by forming ad addn compd with PA)

197)L.F.Audrieth,USP 2410801(1946) & CA **41**, 866(1947) [A non-fulminating primer mixt contains $KClO_3$ 51, $Sb_2S_3$ 34, $(SCN)_x$ 10 & LA 5% or $KClO_3$ 64, $Sb_2S_3$ 21, $(SCN)_x$ 10 & LA 5%] 198)C.Français,FrP 856366(1946) & CA **42**,2774 (1948) [A non-corrosive initiating mixt consists

of MF 38, $Ba(NO_3)$ 30, $Sb_2S_3$ 15, $CaSi_2$ 10 & $PbO_2$ 7%; the $PbO_2$ & $CaSi_2$ may be replaced by RDX] 199)J.D.Brandner,USP 2415001(1947) & CA **41**,2578(1947) [Diisopropanolamine trinitrate (mp 119.6°) is a secondary HE particularly suitable as a base chge in compd detonators. It is highly resistant to shock or friction but is readily detonated by primary expls] 200)C.J. Bain & L.R.Carl,USP 2415806(1947) & CA **41**, 2901(1947) (Compd detonators for use in ammunition contain a main chge of a nitrocompd, a primary chge of LA and an igniter of $Sb_2S_3$, $KClO_3$ & LA) 201)G.F.Rolland,USP 2422043 (1947) & CA **41**,5725(1947)(A compd detonator contains a base chge of PETN and a superimposed initiating chge of 75 DADNPh & 25% HNMnt) (Compare with Ref 192) 202)O.A.J.Gurton & I.O.Lewis,BritP 787346(1947) & CA **52**,6796 (1958) (Ventless delay elec detonators with reduced tendency to ignite mixts of air & $CH_4$ are made by pressing 0.25g of a PETN or Tetryl base chge into a std No 6 Cu Cap; followed by pressing 0.35g of LA or Al/LA/LSt mixt thereon and then inserting a tightly fitting brass tube, the bore of which has a free air space ca 0.08" long adjacent to the primary expl. A delay compn of Si & $PbO_2$ or Sb & $KMnO_4$ is used to provide delays of 35-332 millisec) 203)L.Rubenstein & B. Compbell, USP 2464777(1949) & CA **43**,6828(1949) [Addn of 4-12% NC(having a fiber length of 30-250$\mu$) to LA reduces its sensitivity & improves its loading characteristics for use in detonators] 204)E.J.Hanley,USP 2476370(1949) & CA **43**, 8683(1949) (An ignition compn for rocket proplnts and other expls comprising Pb 57.8, Se 22.1, Al 2.55, Mg 2.55 & $KNO_3$ 15%, is prepd by mixing the dry powdered components. This mixt is pressed into std Al or Zn caps over a Mg-$KNO_3$ flash chge) 205)W.N.King,USP 2480141(1949) & CA **44**,841(1950) [A mixt more stable at high temp & high humidity than std MF primers, contains basic LSt 40, $Ba(NO_3)_2$ 42, $Sb_2S_3$ 11, NC 6 & Tetracene 1%] 206)W.D.Trevorrow, USP 2484131(1949) & USP 2487906(1949); CA **44**,2247 & 7540 (1950) (Gelling of ignition mixts, prior to application to the igniting element, is prevented by addn of a monohydric alc or acet, up to 20% by vol of the nitrocarbohydrate-solv portion. The ignition mixt is composed of Pb salts of nitrophenols & NS or NC) 207)J.T.Power,USP 2495868(1950) & CA **44**, 7540(1950) (A detonator contg a base chge of nitrated dextrose polymer, such as nitrated glucose polyanhydride) 208)W.A.Filbert, USP 2511669(1950) & CA **44**,9149(1950)[Ignition compn which is characterized by short delay between ignition & full flame, is comprised of BkPdr($KNO_3$ 74, charcoal 15.6 & S 10.4%) accelerated by 5-10% of a double salt of $Pb(NO_3)_2$ & a dibasic Pb salt of 4,6-dinitro-o-cresol. A primary ignition chge suitable for elec ignition of the accelerated BkPdr consists of the foregoing Pb salt 72, $KClO_3$ 18 & NS 10%] 209)R. W.Cairns & R.W.Lawrence,USP 2525397(1950) & CA **45**,4043(1951) (High density blasting gelatin may be detonated at high vel through the use of a blasting cap having a base chge of expl energy equiv to PETN at d 1.45, provided that the closed end of the cap weighs no more than 0.1g) 210)F.Habbel,GerP 803644(1951) & CA **45**,5930(1951). (A detonator cap having an elec ignition device in which the usual priming compn of LSt 20 & LA 80% is replaced by LA alone) 211)H.Elsner,GerP 803645(1951) & CA **46**,1260(1952) [Detonators are made safe for use in the presence of fire-damp by mixing from 3 to 20% of an inert material such as KCl, $Na_2CO_3$, $NaHCO_3$, KBr or wax with both parts of the detonator chge. This chge may consist of a primary chge of MF, LA or LA 65 & LSt 35%; and a secondary chge of PETN or Tetryl. Polycarboxylic acids or their salts(up to 20%) may be added to the secondary expl to improve the fire -damp safety of blasting caps] [See also GerP 919156(1954) & CA **52**,14172(1958)] 212)T. Sakamaki,JapP 147(1951) & CA **46**,11690(1952) (Pb or Ag salt of dinitroresorcinol contg 5% of collodion as a binder, or a mixt of Pb dinitroresorcinate 55, $KClO_4$ 20, S 10, Al powd 10 & collodion 5% is used in an elec blasting cap) 213)J.F.Kenney,USP 2589703(1952) & CA **46**, 5320(1952) [A new cryst form (cubic) of LSt suitable for use in primers & detonators is described. The new form is claimed to be less sensitive to static elec and compns contg it have greater and more uniform impact sensitivity & improved burning characteristics] 214)S.D. Ehrlich,USP 2597926(1952) & CA **46**,7771(1952) (Substantially uniform wts of PETN, contg 0.25-4.0% of finely divided graphite, can be charged into detonators whereas in the absence of graphite varying wts result. Also, the graphite reduces the tendency of PETN to adhere to surfaces with which it comes into contact) 215)C.P.Spaeth & C.P.Williams, USP 2607672(1952) & CA **47**,4048(1953) (A stable, gasless, ignition or delay compn for use as a

loose chge in elec blasting caps consists of Bi 48, Se 47 & $KClO_3$ 5% and Bi 61, Se 36 & $KClO_3$ 3%, all as 200-mesh powds) 216)Société Alsacienne d'Explosifs et d'Applications Chimiques,FrP 1023552(1953) & CA **52**,3346 (1958) [A friction detonator for expls contains a nylon cord with a pearl on its end encased in a sheath of an abrasive paste(50g glass powd, 20g $KClO_3$, 7g gum & 3cc w). On drawing out the cord its end passes through a pellet(constg of $Sb_2S_3$ 40, $KNO_3$ 45, MF 10 & gum 5%) that forms part of the detonator. The pearl assures an ultimate energetic friction of the sheath material which ignites the pellet] 217)W.J.H. Schneider,FrP 1026869(1953) & CA **52**,5826 (1958)[Tribasic Pb picrate,[$Pb(C_6H_2N_3O_7)_2$.-3PbO.2.5$H_2O$], is proposed as an igniter; its expln point is 160-180° and ignition delay 0.6, 1.5 & 4.7 sec at 260°, 250° & 240°, resp] 218)E.Habbel & H.Elsner,GerP 889575(1953) & CA **52**, 11426(1958) (Use of equal amts of DADNPh & butyl acetate, thickened with 5% collodion cotton, in elec primers prevents expln of $CH_4$-air mixts in mines) 219)J.F. Kenney,USP 2689788(1954) & USP 2702746(1955); CA **49**,7250 & 7856(1955) [Priming mixts contg a complex or double Fe salt of Styphnic Acid & hypophosphorus Acid [$C_6H(NO_2)_3O_2]_3Fe_2$.-2Fe$(H_2PO_2)_3$ are described. Typical compns contain the above double Fe salt 4, normal LSt 38, $Ba(NO_3)_2$ 25 & Powdered glass 33%; or the above double Fe salt 5, normal LSt 41, Tetracene 4 & $Ba(NO_3)_2$ 50%. A primer suitable for firing indoors contains the double Fe salt 40, $Ba(NO_3)_2$ 25 & Glass 35%. Here no Pb or other toxic substance is used] 220)H.Wippenhohn,GerP 919694 (1954) & CA **52**,14172(1958) (The addn of 0.3-5% graphite or talc to PETN or other expl lessens its sensitivity to friction while filling into the cover hose of detong fuses) 221)J.Barlot,FrP 1071630(1954) & CA **53**,3698(1959) (Stable priming expls which are sens to moderate shock and to temps of 100-200° are prepd by mixing aq or alc solns of nitrates of bivalent metals with aq or alc solns of $N_2H_4$. Prepn & props of Ni, CO, Zn, Cd & Mn derivs are described) 222)J.F.Kenney,USP 2702745(1955) & CA **49**, 7856(1955) [A priming mixt is made(w/o the use of an abrasive) of normal LSt 36, K styphnate-Pb styphnate-Pb hypophosphite complex salt 10, Tetracene 4 & $Ba(NO_3)_2$ 50%] 223)A.O.Franz, USP 2708623(1955) & CA **49**,14326(1955) (A priming mixt for ammunition consists of DADNPh 20, Tetracene 5, Pb salt of ethylenedinitramine 25, Ca silicide 20, $Ba(NO_3)_2$ 24 & $PbO_2$ 6%; gum arabic, 0.5%, is used as a binder) 224)G.A.Noddin & C.P.Spaeth,USP 2717204(1955) & CA **50**,2174(1956) (An initiating chge for use in elec blasting caps is made of grained red P 99 & amor B 1%. Such a mixt is claimed to be readily ignitable and to have a controlled rate of combustion) 225)J.F.Kenney,USP 2728760 (1955) & CA **50**.7462(1956) [The K salt of 2,4 -dinitro-6-(tetrazeno)-phenol (a dk-red cryst ppt which dec explosively at ca 200°) is proposed as an ingredient of priming compns] 226)T. Toshima & K.Honma,JapP 5098(1955) & CA **51**, 17170(1957)[A delay compn for millisec delay detonators, composed of Si-Fe 15, Pb chromate 5, $BaO_2$ 75 & minium($Pb_3O_4$) 5%, has a rate of combstn of 0.2 sec/cm in air] 227)J.Prior,GerP 922216(1955) & CA **51**,17170(1957) [Ignition or initiating materials for blasting caps & fuses are made of insol complex compds of heavy metal salts with org hydroxyamines(such as triethanol-amine) and acid radicals like SCN, $ClO_4$, $BrO_3$ & $N_3$ in admixt with oxidg agents. Two readily ignitable flame-sensitive complexes listed in the patent are: [$CuN(C_2H_4OH)_3CuO$]SCN & [$PbN(C_2H_4OH)_3PbO$]$ClO_4$] 228)S.Kikuchi, JapP 6297(1955) & CA **51**,18612(1957) [Priming chges for elec blasting caps may contain Tetracene, DADNPh, Nitroguanidine, LSt, etc. For example: a)Tetracene 70 & DADNPh 30%; ignition point 140° & time of deton 6.9 millisec b)Tetracene 49, DADNPh 30 & NGu 21%; ign pt 131° & time of deton 143 millisec c)Tetracene 70, & LSt 30%; ign pt 140° & time of deton 7.6 millisec. For straight Tetracene ign p is 143° & time of deton 7.7, while for straight DADNPh they are 166° & 9.2 millisec] 229)S.Okubu & S.Ikunuma,JapP 6898(1955) & CA **51**, 18612(1957) (Cupric azide, stabilized with polyvinyl alc or gelatin and molded in the form of grains which dry into chips, is used with RDX as a base chge for blasting cap compns) 230)T.Toshima et al,JapP 8498(1955) & CA **51**,18612(1957) (An ignition delay compn, composed of $BaO_2$ 83.0, p-nitrophenylazo-2-naphthol 1.5, NS 1.5 & Fe oxide 15.0, ignites at 350° and burns below 600° after a 4-sec delay) 231)T.J. Mulqueeny,USP 2740703(1956) & CA **50**,9742(1956) [Ignition compns for blasting caps & detonators are made of $PbO_2$ 10-40(produced in situ) & Se 60-90%; less erratic firing is obtd than when these ingredients are mechanically mixed] 232)I.O. Lewis,USP 2749226(1956) & CA **50**,13444(1956) [A delay compn for elec detonators contains $Pb_3O_4$ 91-5 & Si 95-9%(of particle size 5-20μ). Such a

mixt, when compressed at 15tons/in$^2$ & loaded into tubes 0.130" ID, burns at 10millisec/mm] 233)R.G.Guenter,USP 2775200(1956) & CA **51**, 3999(1957) (A detong device, which does not req highly sensitive expls, is made of RDX 80, NC 19.7 & DPhA 0.3%. The resulting compacted primer compn is water-resistant and stable up to 1000°F) 234)W.Friedrich,GerP 945010(1956) & CA **52**,15071(1958) (Compds of Bitetrazole with org polynitro compds are suitable expl primers with relatively low sens to friction and high sens to shock & flame) 235)G.A.Noddin & C.P. Spaeth,(Listed in CA as C.P.Spaath) GerP 941473 (1956) & CA **52**,15072(1958) [Primers with delay action which can be regulated to ca 100 millisec) consist of a mixt of B 0.5-3 & $Pb_3O_4$ 99.5-97% with 0.5-1.5% granulating compds(such as polyethylene glycols). These mixts can be stored even in wet & warm rooms; they show no tendency to self-ignite and they burn thoroughly] 236)F.R. Seavey,USP 2767655(1956) & CA **51**,5424(1957) (An improved plastic blasting cap is made by incorporating 1p vinyl rubber to 3-4ps resin in its fabrication. These caps are loaded with pre-pelleted RDX as detonator. LA is used as initiator & LSt as igniter) 237)T.G.Blake,USP 2771034 (1956) & CA **51**,3999(1957) (An improved safety blasting cap contains Pb ethylenedinitramine as an initiator, either alone or with modifiers) 238)W.Maxwell,GerP 953506(1956) & CA **53**, 18488(1959) (Nonflammable filling for safety blasting detonator chges consists of GuN 45-66, K peroxysulfate 27-45, $Cu_2Cl_2$ 6-10 & petrolatum 1%. Thermal decompn of the mixt initiates deton of safety-blasting chges but it will not ignite a $CH_4$-air mixt contg 9% $CH_4$) 239)K.Hino, et al, JapP 1142(1957) & CA **53**,719(1959) (Safety delay compns for blasting caps are improved by adding $Sb_2O_3$ to prevent large heat evolution) 240)M.Yamada et al, JapP 6294(1957) & CA **53**, 719(1950) [A safety delay compn for blasting caps is composed of Cu powd(reduced with H or CO>500° in the presence of $Na_2CO_3$) 30, $Pb_3O_4$ 70 ferrosilicon 5ps. It is claimed that sparks and flames from such blasting caps are inhibited by absorption of alkali ions on the surface of the Cu powd] 241)H.Schlüter & R.Meyer,GerP 957195(1957) & CA **53**,10765 (1959) [The sensitivity of gelatinous detonators (constg of collodion cotton 0.8-2.0, TNT 0-6.0, AN 40-60, woodmeal 0-5.0 & red Fe oxide 0.2%) is increased by the addn of 4.0-25% of pumice, SiO2, corundum, glass pdr or feldspar] 242)H.A.Lewis & G.A.Noddin,GerP 964936(1957) & CA **54**,,900(1960) [A retarded-action fuse for blasting in mines is comprised of a central retarding Pb tube which separates the primer thermic chge. For example, 0.25g LA on each side serves as a primer, followed by 0.0065g of a heat-sens mixt of Al 50, Tetracene 25 & HNMnt 25%, and then 0.097g of an exothermic mixt of Mg 30, $BaO_2$ 35 & Se 35% in a closed bronze capsule; the result is a time lag of 17msec] 243)J.S. Glasby & C.R.L.Hall,GerP 1006770(1957) & CA **54**,18962(1960) [A delay ignition compn is made of Ti metal (5-35μ particle size), $PbO_2$ or $Pb_3O_4$ 50-90%, possibly Si, B, Al or Mg(5-25%) & inert diluent(< 10%), such as NaCl, $Fe_2O_3$, MgO or $CaF_2$] 244)Schaffler & Co, AustralianP 196295 (1958) & CA **52**,6796(1958) [A delayer mass, for delayed-action caps with a short delay time, consists of a mixt of powd Si, $Pb_3O_4$ & $PbO_2$($PbO_4$/$PbO_2$ ratio 78/22) with approx 5-10% of powd graphite as a lubricant] 245)T.J.Mulqueeny & F.R.Seavey,USP 2825639(1958) & CA **52**,7704(1958) (An expl train for elec detonators & blasting caps consists of a RDX base chge, a LA initiating chge and an ignition chge of loose dry MF 30-50 & ground proplnt powd 50-70%) 246)H.M.Kerr & G.Towell, USP 2830885(1958) & CA **52**,11426(1958) (Gasless, slow-burning, stable delay compns for use in delay fuses & particularly in ventless delay elec blasting caps are made of a fuel 6.5-65 and oxidg materials 35-93.5%. Thus a mixt of Se 1.6, Si 6.2, $Pb_3O_4$ 36, $PbCrO_4$ 35.9 & $BaCrO_4$ 20.3% in a 0.125" diam fuse showed a delay of 1.76-9.80sec in columns of 0.30-1.50 length) 247)M.G. Berman et al, USP 2849300 (1958) & CA **52**,21112 (1958) (An igniter consists of 2 components: one a starter mixt, the other a combustion-sustaining mixt. The starter mixt consists of AN 82-85, charcoal 10-12 & $K_2Cr_2O_7$ 4-6%; the combustion mixt consists of AN 86, C 5-8 & paraffin wax 3-6%. Both components are compressed & dipped in paraffin wax) 248)W.Dick,BritP 800136(1958) & CA **53**,7598(1959) [Flexible detong fuses, constg of a core(2.85g) of PETN or RDX & 0.15g of Na carboxymethylcellulose or Na alginate per ft of fuse, are enclosed in a paper tube and wound with jute & cotton yarn. A coating of wax or bitumen at 100° & a waterproof coating of polyethylene are then applied] 249)H.P. Jenkins & C.H.Shomate,USP 2865726(1958) & CA **53**,5680(1959)[A method of controlling the rate of deton of primary or initiating expls such as LA or MF through the addn of waxy materials & metal salts of fatty acids is described. When more than 40% of additive is present, delay

functioning of the chge becomes appreciable. The following mixts, pressed at 12 tons/$in^2$ into 1/8" test cylinders(av column lengths of 0.901 -0.908"), gave the following results: LA/Al stearate, 57.14/42.86(for 0.902") 108±35 microsec delay; 50/50(for 0.901") 354±161; and 44.44 /55.56(for 0.905") 816±108; LA/stearic acid 50/50(for 0.908") 591microsec delay] 250)W. Maxwell et al,GerP's 1035033 & 1036139(1958) & CA **54**,23333(1960) [Heating masses for initiating the thermal decompn of non-detonating safety expls. An improved (2nd patent) delay compn(3 secs) consisted of *Main* chge of 170g of a mixt of $Mg(NO_3)_2.6H_2O$ 49.2, AN 38.8 & sawdust 12.0% in a waxed paper sleeve. It was fed into a 680-cc steel container with an inner diam 31.7mm, the breaking strength of which was 1890kg/$cm^2$. The heating app consisted of a paper sleeve which contained an elec blasting cap and 20g chge of Amm sulfate 35, GuN 61.5, CuCl 2.5, kaolin 0.5 & castor oil 0.5%] 251)A.Florin et al, GerP 1036735(1958) & CA **54**,16833(1960) (Priming compns for fuses of improved ignitability are made of LA coated with chromates, plumbates or manganates sl sol in w) 252)D.T.Zebree, USP 2867517 & 8(1959) & CA **53**,5679(1959) (A blasting initiator having high ignition temp, improved safety in handling & excellent firing props in elec delay blasting caps consists of a mixt of finely divided Pb 37-81, Te 19-65ps & an additive such as Mg, Al, Si, S or P. In addn to the above materials 0.1-6.0% of Pb or other stearate, palmitate or laurate is used to improve firing accuracy) 253)S.Kinoshita & T.Yamazaka,JapP 95(1959) & CA **53**,20807(1959) (A delay compn for elec detonators, having decreased heat of combustion consists of $BaO_2$, $Cr_2O_3$ & a small amt of org compds such as resin, rubber, oil, plastic & DNT) 254)H.Williams & W.A.Gey, USP 2900242(1959) & CA **53**,22957(1959) (An ignition compn suitable for igniting solid propellants consists of a mixt of polytrifluoroethylene 50, $NH_4ClO_4$ 50 & B 5.5-7.5ps) 255)C.A.Stokes,USP 2902351(1959) & CA **53**, 22957(1959) [An igniting compn is made of a thixotropic mixt of pyrogenic $SiO_2$(50-100mm particle size) & 8-10% of a high-boiling aliphatic hydrocarbon. This mixt is suitable for igniting difficultly-ignitable solids] 256)D.J.Andrew et al, BritP 815532(1959) & CA **54**,1852(1960) [A high-rate detong fuse is formed by reducing the no of grains of expl(PETN,RDX,HNMnt, LA or LSt) per linear ft of chge and by enclosing the expl in a metal sheath such as Pb, Al, Sn, Ag, Cu, Mg or their alloys] 257)D.T. Zebree,USP 2908559(1959) & CA **54**,2745(1960) (An elec initiating device having a delay fuse element and a loose ignition mixt of Pb 72.4, Se 27.6 & Si 1-5ps; addn of Si increases the heat of combstn of the mixt) 258)W. E.Schulz, USP 2882819(1959) & CA **53**,12681(1959) (An elec blasting cap, less sens to static elec is formed by surrounding the bridge wire with an ignition chge of LSt in a polyvinyl acetate binder and imbedding this in a static-insensitive but volt -sensitive chge of Mg 30, $BaO_2$ 35 & Se 35% which is ignitable by the ignition mixt) 259)R.E. Donnard,USP 2887370(1959) & CA **53**,15570(1959) [A non-corrosive primer mixt that ignites proplnts consists of LSt 30-7, $PbO_2$ 5-10, $Ba(NO_3)_2$ 30-5, Tetracene 3-4, PETN 0-5,$Sb_2S_3$ 10-15 & Zr 5-10%] 260)D.T.Zebree,USP 2892695(1959) & CA **53**, 17514(1959)[Detonators with relatively low spread in firing time are made with a delay fuse contg 60% of a mixt of $BaO_2$ & Se, Te or S(75/25) and 40% of an alloy of Pb & Sn(85/15)] 261)Manufacture Générale de Munitions,FrP 1184312(1959) & CA **54**,20210(1960) (A non-corrosive primer for ammunition contains LSt 33, Tl nitrate 40, $CsNO_3$ 10 & $Sb_2S_3$ 17% or LA 35, Tl nitrate 35, $CsNO_3$ 20 & $Sb_2S_3$ 10%) 262)G.W.C.Taylor & S.E. Napier,BritP 828148 & 9(1960) & CA **54**,13666 (1960) [Expl materials suitable for use in delay or priming compns(such as LA,LA-PETN & LSt) are prepd by separating them from an aq soln of the Na salt of carboxymethyl cellulose or by suspension in a gelatin soln contg a flash-sens material(such as Pb 2,4-dinitroresorcinate) which almost completely coats the expl particles] 263)G.W.C.Taylor,BritP 836410(1960) & CA **54**, 20209(1960) [Prepn of expls(such as Ba styphnate monohydrate, LA & DADNPh) particularly suitable for delay or priming compns, by pptg them from an aq medium in the presence of 2% of a colloidal mixt of the Na salt of starch, amylpectin or amylose glycolate is described] 264)K.Ogawa et al,JapP 12093(1960) & CA **54**,25829(1960) (An elec detonator in which a semiconducting SiC powd or a mixt of Si & Zr is placed between two electrodes, above which is placed a primary powd for ignition at low voltage)

**Blasting Caps and Detonators, Initiating Efficiency of.** See under Initiating Efficiency; Vol 1,p XVIII

**Blasting caps and Detonators, Tests of.** See Vol 1 of this Encyclopedia under Esop's Test

for Efficiency of Detonators, p XI; Grotta's Test for Detonators,p XV; and Initiating Efficiency of Initiating Explosives, Blasting Caps & Detonators,p XVII

**Blasting Coal, Apparatus for.** See Vol 1,p A474-L

**Blasting Devices.** See Active List of Permissible Explosives and Blasting Devices; Vol 1,p A101-L

## BLASTING EXPLOSIVES

Explosives used in blasting operations(such as in quarry work, non-gaseous mines, strip-coal mines, metal mines, ditching, stump blasting, hole drilling or in the demolition of buildings, roads, bridges, railroad tracks, sunken ships, under-water obstacles in channels, etc) are called blasting explosives. Nitroglycerin Dynamites, Gelatin Dynamites, Black Powder, liquid air, carbon dioxide & oxygen are the materials used for commercial blasting & demolition work. For military demolitions it is more convenient to use TNT and plastic explosives(containing TNT, PETN & RDX with other ingredients). The short flame duration and low temp of deton reqd of permissible expls are not reqd in most blasting operations. Blasting expls are initiated by means of blasting caps(see above)

The principle factors which govern the choice of a coml blasting expl are power, brisance, density, sensitivity, stability, water-repellancy & cost. These factors assume varying degrees of importance according to the circumstances under which the expl is to be used. For blasting very hard rock(such as gold quartz) a very powerful and brisant expl is required. As underground drilling is expensive, the density of the expl should be high. Blasting gelatin is suitable for such purposes, provided it is fired with a detonator powerful enough to produce a vel of deton of ca 7000m/sec(if fired with a detonator of only moderate power the vel of deton may be as low as 1500m/sec). In quarrying & strip-mine operations where the work is done in the open, large drills are used and expl charges from 4 to 6" in diam(and even greater) are reqd. For such work TNT, either alone or in composite expls, is very suitable but the cost is usually prohibitive. For under-water blasting, water-proof expls such as Gelatin Dynamites, TNT or Pentolite should be used. Other expls can be used provided the cartridges are thoroughly water-proofed. It should be noted that the effect produced by an expln under water is considerably less than it would be on land due to the press of the surrounding water. For agricultural purposes such as digging ditches, removing tree trunks & breaking hard soil, expls of low power & brisance, such as Black powder or low-strength Dynamites, should be used(see "Agriculture and Forestry Uses of Explosives" in Vol 1,p A112-R)

For work in gaseous coal mines the expls must be of low brisance(in order not to break the coal into small pieces) and of low expln temp(in order not to ignite the firedamp and coal dust in mines). Also, the amount of carbon monoxide developed should not exceed about 2000 liters/kg of expl. Such expls are known as safety or permissible expls

US blasting expls are manufd by DuPont Co, Hercules, Atlas, Olin-Mathieson, Spencer, Trojan & some other firms. Although each company uses its own production formulas, there is some info in open literature on this subject. Many expls suitable for blasting(US and foreign) are described in Vol 1: such as Akremite(p A119-L), Aldorfit(A123-R), Alkalites(A127-R), Almatrites (A140-L), Alumatol(A141-R), Aluminum-Containing Expls(A146-L to A155-R), Amasite(A157-R), Amatex(A157-R), Amatols(A158-L to A165-R), American Ammonium Nitrate Dynamites(A355, table), American Dynamites(A167-L), Amidogène (A171-R), Ammoksil(A286-R) Ammons(A286-R), Ammonal(A287 to A293-R), Ammoncarbonites(A293 -L), Ammondynamit(A293-R), Ammondyne(A293-R), Ammonex(A293-R to A 295-R), Ammongelatine Dynamit(A295-R), Ammogelignite(A295-R), Ammonite(A307-R to A310-L), Ammonite-Goudronite A310-L), Ammonium Nitrate Blasting Expls(A341 -L to A354-R), Ammonium Nitrate Dynamites(A355 -L to A356-R), Ammonium Nitrate Gelatin(A367-R & A368, table), Ammonpentrinit(A382-L to A382-R), Ammon-Semigelatin(A382-R), Amonal 1(A391-R), Amvis Expls(A393-R), Anchorite(A401-R), Arkite (A480-R), Arnoudts' Expl(A486-R), Asphalines (A496-L), Astralit(A497-R) and Aunt Jemima Expl (A507-R)

Blasting expls starting with letters B to Z will be described in vols 2 & others

The following German blasting expls(past and present) are described in PATR **2510** (Ref 8): Alkalsit(p Ger 3), Amatols(Ger 4 & 44), Ammonal (Ger 4), Ammoncarbonit(Ger 5), Ammondynamit (Ger 5), Ammongelatine(Ger 5), Ammonit(Ger 5,30 & 44), Ammon-Nobelit(Ger 5), Astralit(Ger 10), Bikarbit(Ger 11), Calcinit(Ger 27), Carbonit(Ger 25), Cheddit(Ger 27), Chloratit(Ger 28), Chrom -Ammonit(Ger 28), Commercial Expls(Ger 29),

Dahmenit(Ger 32), Demolition Expls(Ger 34), Detonit(Ger 35), Donarit(Ger 30 & 38), Dualin(Ger 38), Dynamit(Ger 30 & 39), Ersatzsprengstoffe (Ger 43), Fördit(Ger 52), Formit(Ger 52), Fulmenit (Ger 53), Gelatine-Astralit, -Carbonit, -Cheddite & -Dahmenit(Ger 66); Gelatine-Donarit(Ger 30 & 66); Gelatine-Dynamit, -Leonit & -Prosperit(Ger 67); Gelatine-Romperit & -Tremonit(Ger 68); Gelatine-Wetter-Astralit & -Nobelit(Ger 68); Gelatit & Gesilit(Ger 68); Gesteins-Albit, -Dorfit, -Koronit, -Permonit,-Persalit & -Westfalit(Ger 69); Haloklastit(Ger 87), Hexa Expls(Ger 44 & 88), Kessen Expls(Ger 101), Kinetit(Ger 101), KMA Expl(Ger 44); Kohlen-Carbonit, -Koronit & -Salit (Ger 101); Kohlen-Westfalit(Ger 102), Kolax(Ger 102), Koronit(Ger 102), Neurodit(Ger 116), Neudahmenit(Ger 117), Neunobelit(Ger 117), Neuwestfalit(Ger 117), Nitrobaronit(Ger 118), Nitrolit, Nobelit & Nobel's Wetterdynamit(Ger 122); Perchloratit(Ger 128-9), Perchlorit(Ger 129), Percoronit & Perkoronit(Ger 129-30); Perdit & Permonit (Ger 129); Persalit & Petroklasist(Ger 130); Roburit (Ger 160), Romperit(Ger 169), S-16 & S-19 Expls(Ger 44); Sekurit & Sekurophor(Ger 174); Stonit(Ger 191), Tetansprengstoffe(Ger 196), Thunderit(Ger 198), Totalit(Ger 199), Tremonit(Ger 203), Unterwassersprengstoffe(Ger 212), Westfalit(Ger 226) and Wettersprengstoffe(Ger 226 & 262 and tables on pp Ger 260-1. These include Wetter-Agesid, -Albit, -Ammoncahüsit, -Arit, -Astralit, -Baldurit, -Barbarit, -Bavarit, -Carbonit, -Dahmenit, -Detonit, -Donarit, -Dynamit, -Dynammom, -Fördit, -Fulmenit, -Lignosit, -Markanit, -Monakit, -Nobelit, -Perchlorit, -Persalit, -Salit, -Siegrit, -Sonnit, -Wasagit, -Westfalit & -Zellit)

For *military demolition* purposes, the following explosives have been used:

**USA**: TNT(demolition blocks), NS,RDX Compositions C, C-2 & C-3(plastic), Tetrytol, Pentolite, AN (cratering), Dynamites & Blasting Gelatin(Ref 3,p 3)

**GtBrit**: TNT, TNT/Tetryl-70/30, Expl 808(Desensitized Polar Blasting Gelatin), TNT/PETN -50/50 or 75/25, Ammonal and Gelignite(Ref 3, pp 126-127)

**Germany**: TNT, PA, TNT/PETN/wax, Plastite (RDX/OIL), RDX/PETN & PETN/wax(Ref 3, 129 -131)

**France**: Melinite(Picric Acid) (Ref 3,p 135)

**Italy**: TNT, PETN(Ref 3,p 136)

**Japan**: PA(compressed or cast), RDX/vegetable oil-80/20(plastic) (Ref 3,pp 133-134)

**Russia**: TNT in rectangular blocks 5x5x10cm & 5x2.5x10cm, weighing 400g & 200g or in cylindrical blocks 7cm long & 3cm diam, weighing 75g. They were used during WWII(Ref 3a)

*Refs*: 1)Marshall **2**(1917),p 569 2)Meyer(1943), pp 392-400 3)Anon, "Explosives and Demolitions" USDept of Army Field Manual FM5-25(1945) 3a)Blinov **1**(1948),17 4)OlinIndsInc,Explosives Products Bull, 2nd(1950) 5)Kirk & Othmer **6** (1951),pp 60-74 6)Blasters'-Hdb(1952) 7)W.de C.Crater et al, IEC **50**,No 7,40A(1958) 8)PATR **2510**(PB Rept **161270**) (1958)

**Additional References on Blasting Explosives**

1)H.D.Farris & A.C.Jex, USP 891334(1908) & CA **2**,2995(1908) [$KClO_3$ 66lb, wheat flour 33lb, PA 1oz(all blended and coated with 1 gal coal oil), $HNO_3$ 1.5oz & HCl 1oz]

2)W.Eberle,FrP 392378(1908) USP 910365(1909); CA **3**,1088(1909) & CA **4**,2733(1910) ($KNO_3$ 12, S 3, charcoal 1 & pulverized horse dung 1p)

3)C.Pieper, BritP 15916(1908) & CA **4**,112(1910) ($NH_4ClO_4$ 42, $NaNO_3$ 31, TNT 14 & paraffin wax 13%)

4)H.D.Farris & A.C.Jex, BritP 20574(1908) & CA **3**,1929(1909) [KClO 53, $KNO_3$ 5, $Ca(OH)_2$ 6, wheat flour 33, PA & $KClO_3$ 2 and lamp black 1%]

5)(?)Klaffke, FrP 396496(1908) & CA **4**,2733(1910) ($KNO_3$ 73.9, carbon 13.4 & cellulose 12.7%)

6)H.F.Easton, BritP 18551(1909) & CA **5**,198(1911) [$Ba(NO_3)_2$ 80, TNT & Al powd 20%]

7)G.M.Peters & M.F.Lindsley, USP 953798(1910) & CA **4**,1678(1910) (AN 75, nitrated wood fiber 20, nitrobenz 4 & asphalt 1%)

8)C.Arnoudts, USP 964365(1910) & CA **4**,2733(1910) ($KClO_3$ 60, sugar 40, turpentine 2, vegetable tar 2 & $KMnO_4$ 0.00125ps)

9)J.E.Bronstein, USP 986900(1911) & CA **5**,1995 (1911) [AN 82.2, sugar 9 & Fe pyrites($FeS_2$) 8.8%]

10)G.M.Peters & M.F.Lindsley, USP 994273(1911) & CA **5**,2557(1911) [AN 67, NaCl 20, nitrated wood fiber 10, asphalt (20% soln in nitrobenz) 2 & $CaCO_3$ 1%]

11)G.M.Peters, USP 1048578(1913) & CA **7**,703 (1913) [AN 75, nitrated potato meal 20 & asphalt (20% soln in MNB) 5%]

12)A.B.Cole, USP 1126401(1915) & CA **9**,717(1915) ($KClO_3$ 30, sugar 25, coal or coke powd 22, $NaNO_3$ 20, MeOH 2, $KMnO_4$ 0.5 & lampblack 0.5%)

13)C.Schanandoah, USP 1141009(1915) & CA **9**, 1845(1915)[Alum 1 & sugar 16ps (moistened with coffee extract and boiled with MeOH until dry) mixed with 1 1/2 times its wt of $KClO_3$ just prior to use]

14)K.Arklow & L.H.Pirmez, BritP 110237(1916) & CA **12**,428(1918) (AN 65, NG 11, wood meal 5

& $CaF_2$ 19%)
15)J.L.Donner, USP 1214765(1917) & CA **11**,1042 (1917) [Sugar 45-48 & $H_2O$ 1-2(melted) and successively added: $MnO_2$ 1-2, crude petroleum 1-2 & $KClO_3$ 46-49% and the mixt granulated and dried]
16)O.B.Carlson & E.F.Otterdahl, USP 1277043 (1918) & CA **12**,2127(1918) [$NH_4ClO_4$ 70-85, Fe-Si 5-15, wood meal 1-10, mineral oil(fraction bp above 250° and rich in naphthenes) 2-15 & NC(gelatinized with "liq TNT") 5-20ps; $NaNO_3$ is added if the expl is used in mines]
17)W.Rintoul & T.J.Nolan, BritP 131389(1918), USP 1348741(1920) & CanP 217254(1922); CA **14**, 350,2989(1920) & **16**,1868(1922) [NC(12.2%N) 50, NG 41, benzyl-p-tolylurethan 8.5 or phenylbenzylurethan 8 & ethyl-β-naphthyl ether 0.5 or diphenylurethan 1%]
18)L.O.Bryan & W.R.Swint, USP 1327859(1920) & CA **14**,843(1920) ($NaNO_3$ 43-57, TNT 18-51, NG 5, wood pulp 0-5, cornmeal 0-8, S 0-7 & $CaCO_3$ 1%)
19)R.L.Hill, USP 1334303 & USP 1360397-9(1921); CA **14**,1609(1920) & **15**,599(1921) ($NH_4ClO_4$ 45-55, NS 35-45 & $NaNO_3$ 10%; a small amt of oil, a liq nitrocompd, $MnO_2$ & S may also be added)
20)J.R.Mardick, USP 1335788 USP 1335790(1920) [TNT(or PA) 20, Fe-Si(82%) 12, AN 40, $NaNO_3$ 21.5, DNT 3, woodflour 3 & $CaCO_3$ 0.5%; TNT(or PA) 25, Fe-Si(82%) 7,$KClO_4$ 50, $NaNO_3$ 12.5, woodflour 5 & $CaCO_3$ 0.5%; TNT(or PA) 20, Fe-Si (82%) 12, $NH_4ClO_4$ 35, $NaNO_3$ 26.5, DNT 3, woodflour 3 & $CaCO_3$ 0.5%; or AN (coated with 3% gelatinized DNT) 40, TNT 15, DNT 32 & Fe-Si 10%]
21)A.Langmeier, USP 1367608(1921) & CA **15**, 1077(1921) [$NaNO_3$,(coated with TNT) 49, $NH_4ClO_4$(coated with TNT) 20, TNT 20, S 10 & woodpulp 1%]
22)P.N.Stankovitch, USP 1412319(1922) & CanP 229108(1923); CA **16**,2226(1922) &**17**,2051(1923) [$NaNO_3$, flour middlings(med size particles separated in sifting ground grain) & S impregnated with a 10-20% soln of DNT in NG]
23)L.O.Bryan, USP 1420364(1922) CA **16**,2992 (1922) (NC 40-65, $NaNO_3$ 30-50, Al pdr 0.3-5, NG 1-10 & $CaCO_3$ 1%)
24)E.M.Werner, USP 1430272(1922) & CA **16**,4067 (1922) [$NaClO_3$ 70.5, sugar 18.75, Al powd 3 & resin(20% soln in nitrobenz) 7.75%]
25)E.I.duPont, BritP 184487(1922) & CA **17**,211 (1923) [Ground smokeless proplnt(mainly NC), Cordite,$NaNO_3$, chalk & $H_2O$]
26)A.J.Strane,USP 1455309(1923) & CA **17**,2365 (1923) (Mixt of colloided NC powd & BkPdr)
27)L.Yonck, BritP 216061(1923) & CA **18**,3479 (1925) (Hollow solid cylinder of cast TNT, PA or mixt TNT/PA filled with a powd mixt of AN & nitrated hydrocarbons)
28)R.L.Hill,USP 1483087(1924) & CA **18**,1053(1924) [AN 17.5-52.5, NG or Tetranitrodiglycerin 3-3.5, $NaNO_3$ 24-52,5, $CaCO_3$ 0.5, nitroaromatic compds (at least 50% TNT) 20-4 & S 0-2ps]
29)J.Marshall, USP 1509362(1924) & CA **18**,3722 (1924) [Ground smokeless proplnt (gelatinized with 1-10% DNT) 25% with $NaNO_3$, $CaCO_3$ or Al added]
30)L.O.Bryan,USP 1509393(1924) & CA **18**,3722 (1924)[AN, ground smokeless proplnt, NG, NaCl, $NaNO_3$ & $CaCO_3$]
31)W.M.Dehn, USP 1509935(1924) & CA **18**,3722 (1924) ($NaNO_3$ 1-4, sawdust 1.5-6.0 & AN 3-7ps)
32)F.Olsen, USP 1510555(1924) & CA **18**,3722 (1924) [$NH_4ClO_4$ 0-40, TNT 0-50, smokeless proplnt 15-50, combustible non-expl material(such as woodmeal or "vegetable ivory") 3-10, paraffin 0-30, $KNO_3$ 0.30 & $MnO_2$ 0-30ps]
33)C.D.Pratt, USP 1563924-6(1925) & CanP 259355-6(1926); CA **20**,505 & 2415(1926) [The constituents of BkPdr($NaNO_3$ 45-65, S 1-15 & charcoal 10-25%) mixed with carbohydrates(starch and/or paraffin) 1-35 & a metallic or $NH_4$ chloride, oxalate or tartrate 1-15% to reduce tendency to ignite flammable gases & dusts]
34)N.A.Unger, USP 1566784(1925) & CA **20**,505 (1926) [AN 50-85, Si 10-40 & NG(gelatinized with NC) 1-15ps]
35)C.D.Pratt, USP 1590393(1926) & CA **20**,3086 (1926)[The constituents of BkPdr mixed with a carbohydrate(cellulose, glucose or starch)& with $NH_4Cl$ in order to lessen their tendency to ignite flammable gases] (Compare with Ref 33)
36)R.A.Long, USP 1698674(1929) & CA **23**,280 (1929) [NG (up to 8%) + TNT(together not in excess of 12%) & ground wood]
37)L.N.Bent, USP 1706517(1929) & CA **23**,2297 [$NH_4BO_3$, $NaNO_3$, NG & ground wood(pine or spruce)]
38)E.Sörenson, USP 1709498(1929) & CA **23**, 2827(1929) (AN 800, $KNO_3$ 100, S 16, $MnO_2$ 15, paraffin 6, petr naphtha 6, rosin 15, potato flour 8, Al 30 & NG 100ps)
39)J.P.Nienhuis, BritP 297365(1927) & CA **23**, 2827(1929) (Oil or asphalt pitch, with or w/o charcoal, $KNO_3$ & S)
40)C.H.Waters, USP 1786046(1930) & CA **25**,595 (1931) [$NaClO_3$ 1, liq MNT 3 & liq DNT 11ps ($NaNO_3$, $CaCO_3$ & sawdust may be added) for stump or rock blasting]
41)P.Naoúm, GerP 513654(1930) & CA **25**,4710

(1931) [$Ca(NO_3)_2$(dehyd above 100°) 62-70%, TNT, charcoal & NG]
42)R.L.Hill, USP 1833573(1931), USP 1845663-4 (1932), USP 1850106(1932) & FrP 716532(1931); CA **26**,1125,2320 & 2867(1932) [$NH_4ClO_4$ or AN (coated with graphite, rosin, paraffin, sand, charcoal, TNT, NC or carbohydrate) mixed with grains of BkPdr]
43)A.S.O'Neil & A.G.Schuricht, USP 1849378(1932) & CA **26**,2867(1932) (NC 88-99 & TeNA 1-12%; other nitrocompds may be added)
44)W.C.Holmes, USP 1905289(1933) & USP 1927832 (1933); CA **27**,3612 & 5981(1933) (NG, MgO & Nitrosugar or NG & ca 0.4% triphenyl phosphate, with other ingredients)
45)Lignosa Spólka Akcyina, BritP 388508(1933) & CA **27**,5981(1933) (AN 66, $NaNO_3$ 12, NaCl 10, woodmeal 10 & charcoal 2%, with 2.75-6.35 qts $H_2O$ per 220 cu in of nitrates & woodmeal)
46)A.C.Scott, BritP 397203(1933) & CA **28**,900 (1934) [AN with $NH_4Cl$, NaCl, $(NH_4)_2C_2O_4$, $NaHCO_3$, $ZnSO_4$, $MgSO_4$ or $Na_2SO_4$ added & asbestos 1-2%; dec by heat and yields non-flammable products when ignited with BkPdr or $KClO_3$ & cellulose acetate]
47)Akt-Ges Lignose, GerP 579815(1933) & CA **28**,1193(1934) (Addn prod of PbO & neutral Pb picrate as principal constituent of blasting chges)
48)W.de C.Crater, USP 1945344(1934) & CA **28**, 2538(1934) (AN, $NaNO_3$ & cryst nitrolactose; woodpulp, TNT, or DNT may be added)
49)W.E.Kirst & J.Marshall, CanP 339433(1934) & CA **28**,2908(1934) (AN 58, NG 15, $NaNO_3$ 9 & cornstalk pitch 18%)
50)C.A.Woodbury, CanP 339468-9(1934) & USP 1965731(1934); CA **28**,2908 & 5672(1934) [NG 86-92, kieselguhr 3-6% & NC; NC 1-5 & dope material 3-10ps (gelatinized with 33-92ps liq nitric ester); NG 90, NC 5, woodpulp or bagasse pitch 5%]
51)H.A.Lewis, CanP 340566(1934) & CA **28**,4234 (1934) (AN 75, O or 52; NG 10, 60 or 23; $NaNO_3$ 5, 20 or 14; treated sunflower stalks 8, 5 or 2; & other combustibles 2, 15 or 19%)
52)A.G.White & ICI, BritP 412583(1934) & CA **29**, 346,1935) (Mixt of NG & NGc 15, AN 8.5, $NaNO_3$ 12.0, plant fiber 6, NaCl 58 & $NH_4H_2PO_4$ 0.5%)
53)C.Wache, BritP 415806(1934) & CA **29**, 1251 (1935) (Mixt of a metallic nitrate & sl nitrated cellulose)
54)J.A.Wyler,USP 1985968(1935) & CA **29**,1252 (1935) (TeMNe & MNX with AN, $NaNO_3$ NS, NC, TNT, Al, ZnO & cornmeal)
55)W.E.Kirst, CanP 350400(1935) & CA **29**,5274 (1935)(AN 5-30, $NaNO_3$ 4040-75. charcoal 1-20, S 1-20 & woodpulp 1-10%, shaped in the form of a block, d 0.9 -1.30) 56)L.E.Clapham, CanP 350872(1935)& CA **29**, 5658(1935) [Mixt of NG & NGc 14.0, AN 44.5, $NaNO_3$ 13.0, NaCl 11.0, peat(5%$H_2O$) 17.0, resin 0.25 & $(NH_4)_2HPO_4$ 0.25%]
57)N.G.Johnson & H. A.Lewis, CanP 350873 (1935), USP 2033196(1936); CA **29**,5659(1935) & **30**,3240(1936) (Three compns: PETN 35.0, $NaNO_3$ 56.0, S 5.0, chalk 3.5 & engine oil 0.5%; PETN 12.0, AN 66.5, $NaNO_3$ 10.0, carbonaceous material 9.0, liq DNT 2.0 & chalk 0.5%; or PETN 16.0, AN 50.0, $NaNO_3$ 21.0, carbonaceous material 9.5, NG 3.0 & chalk 0.5%)
58)D.D.Miceli, FrP 783835(1935) & CA **29**,8335 (1935) [$KClO_3$ 60, "latoz" (?) 20 & boiled potatoes 20%]
59)N.G.Johnson & C.A.Woodbury, CanP 352763 (1935) & CA **29**, 8335(1935) (NG 47.0, DNT 3.0, NC 1.3, $NaNO_3$ 36.1, cereal 9.0, starch 2.7 & chalk 0.9%; NG 60.0, DNT 3.5, NC 2.3, $NaNO_3$ 2.2, AN 24.0, cereal 6.0, starch 1.0, & chalk 1.0%; NG 30.0, DNT 2.0, NC 0.7, $NaNO_3$ 44.8, $NH_4Cl$ 15.0, cereal 2.0, starch 4.5 & chalk 1,0%; and NG 22,0, DNT 1.5, NC 0.2, $NaNO_3$ 9.0, AN 60.0, cereal prod 6.9, & chalk 0.4%)
60)A.Lance, BritP 432308(1935) & CA **30**,617-8 (1936) [Liq O with absorbent cellulosic material (sawdust, cork or peat) mixed with high-bp hydrocarbons (petr jelly or vaseline) up to 20% & other ingredients, such as $MgCO_3$ or kieselguhr 10-15% (to reduce its strength) or Al or Fe-Si(to increase its strength)]
61)Soc Anon d'Arendonck, BritP 432850(1935) & CA **30**,617(1936) [A compn used to prevent ignition of flammable gases in blasting contains potash feldspar with other ingredients. One example: orthoclase($KAlSi_3O_8$) 55, $K_2SO_4$ 35 & plaster of Paris or clay 10%. This compn is preferably made into a sheath surrounding the blasting expl but up to 30% may be incorporated in the expl itself composed of NG 11, DNT 1, NaCl 22, AN 59, cellulose 6.85 & lamp black 0.15%]
62)H.T.Simpson, BritP 435588(1935) & CA **30**, 1564(1936) [A mining & quarrying expl: AN 90, Al(coated with paraffin) 6.5 & $MnO_2$ 3.5%]
63)E.I.duPont, BritP 437035(1935) & CA **30**,3239 (Non-gelatinous blasting expl: AN 58, $NaNO_3$ 20.2, PETN 15, TNT 6, hydrocarbon oil 0.3 & chalk 0.5%)
64)ICIANZ, AustralianP 25791/35 (1936) & CA **31**, 3698(1937) (BkPdr chge in juxtaposition to an exothermic chge of lower rate of combustion con-

sisting of charcoal or woodmeal & AN, alkali metal or Amm perchlorate; finely divided metals or metal-silicon alloys must be absent)
65)R.C.Payn & A.G.White, CanP 362019(1936) &CA **31**,1617(1937) [Cooling sheath for blasting expls: $NaHCO_3$ 100, gelatin soln(10%) 50 & glycerol 10ps is formed into a sheet and dried to a moisture content of 3%]
66)J.Taylor, CanP 362020(1936) & CA **31**,1616 (1937) (Blasting expl for use in fiery mines: AN 60, $NH_4Cl$ 69 & soda ash 2ps by wt of total mix)
67)A.G.White, CanP 362021(1936) & CA **31**,1617 (1937) (Core expl: NG 10, AN <66.5, NaCl <15.0 & woodmeal 8.5% sheathed with a solid cooling material, $NaHCO_3$ & NaF, not exceeding 30% of the wt of the expl core; or Ca silicide 1 & AN 4ps)
68)A.G.White & E.Jones, USP 2075969(1937) & CA **31**,3698(1937) (Safety cartridge or bore hole chge: core of BkPdr & a sheath of Na or Mn borate)
69)F.E.Miller & J.D.McLeod, USP 2078264(1937) & CA **31**,4500(1937) (Nitrated naphthalene mixed with PA, $NaNO_3$ & other ingredients)
70)L.S.Byers, USP 2079105(1937) & CA **31**,4500 (1937) [Alkali chlorate & alkali nitrate mixed together with liq DNT isomers(mp 3-15°) & ground wood(20-60 mesh)]
71)M.F.Lindsley,Jr, USP 2079558(1937) & CA **31**, 4500(1937) [AN, $NaNO_3$, $KNO_3$ or $Ba(NO_3)_2$, tar char & S; paraffin and a coating of NC or NG may be used]
72)P.Parodi-Delfino, USP 2079792(1937) & CA **31**,5165(1937) (Tetraacetate of pentaerythrite with TNT or NC & NG)
73)D.C.McMeans, USP 2109049(1938) & CA **32**, 3156(1938) (Underground blasting expl: $KClO_3$ 35, sugar 35, woodpulp or sawdust 10, DNT 12, toluene 6 & petrolatum 2%)
74)M.A.Nice, USP 2120503(1938) & CA **32**,6064 (1938) (Nongelatinous blasting expl: NG 22-28, AN 26-46%, with NC & woodpulp of flour added)
75)A.Ignatieff & Heaters Ltd, BritP 480330(1938) & CA **32**,6463(1938) [Combustible gas-producing chge: $KClO_4$ 60, salicylic acid 9, castor oil 1 & $(COONH_2)_2$ 30%; $KClO_4$, starch, borax, castor oil & $(COONH_4)_2$; or $KClO_3$, charcoal, $MgSO_4$ & castor oil]
76)A.G.White, USP 2128576(1938) & CA **32**,8782 (1938) (Composite blasting cartridge or borehole chge: BkPdr in juxtaposition to a slow-burning expl mixt, charcoal & AN (Compare with Ref 64)
77)J.Taylor et al, BritP 488584(1938) & CA **33**, 386(1939) [Gas-producing safe blasting chge: GuN 100 & NC(12%N in 40% acet soln) 40ps or urea nitrate 100, NC(12%N) 20 & NC (13%N) 10ps]
78)L.S.Byers, USP 2136205(1939) & CA **33**,1500 (1939) (Blasting powder pellets formed of a core of $NaNO_3$ coated with NG and an outer layer of nitrate, perchlorate & Al)
79)H.G.Pert, USP 2167849(1939) & CA **33**,8993 [A mixt of sucrose 24 & $KNO_3$ 33(both dissolved in hot w) with finely powd coal 10 & $KClO_3$ 33% is grained and dried]
80)H.H.Holmes, USP 2168030(1939) & CanP 384570(1939); CA **33**,9648(1939) & CA **34**,1488 (1940) (AN 15-45, Al 1% and the remainder BkPdr)
81)M.H.Wahl, USP 2171379(1940) & CA **34**, 265 (1940) [Coal mining expl: AN, binding agent & ground smokeless proplnt (50-mesh)]
82)C.O.Davis, USP 2185248(1940) & CA **34**,3092 (1940) [AN 92, DNT or MNN 4 & DPhA or p-toluidine 4%]
83)M.A.Cook et al, USP 2199217-8(1940) & CA **34**, 6078(1940) [Coal mining expl: AN (agglomerated by starch) coated with 10% NG]
84)R.W.Cairns, USP 2211738(1940) & CA **35**,625 (1941) [AN (coated with rosin or dammar & paraffin), NG & woodpulp]
85)A.H.Garcia, USP 2215608(1940) & CA **35**,898 (1941) [Quarry & mine expl: $KClO_4$ 65, $MnO_2$ 1.3, $NaNO_3$ 5, $(CH_2)_6N_4$ 1.4, S 1.3, sucrose 26 & Fe filings lp]
86)M.A.Cook et al, USP's 2220891-2(1940) & CA **35**, 1636(1941) (Blasting expl having d over 1.15 are formed by combining AN >50% with other ingredients)
87)H.G.Pert, BritP 531082(1940) & CA **35**,8299 (1941) ($KClO_3$ 33, $KNO_3$ 33, sucrose 24 & finely powd coal 10%)
88)C.S.Hallet, BritP 530818(1940) & USP 2263406 (1941) & CA **36**,272 & 1496(1942) [Coal mining expl: $KClO_4$, coal-tar pitch, sugar, a dichromate (not over 6%) & an alkali metal chloride(ca 26%)
89)C.H.Winning, USP 2231043(1941) & CA **35**, 3445(1941) (NG & AN, coated with starch, gelatinized in w by thiocyanate, urea or dicyanodiamide)
90)V.H.Williams, USP 2235060(1941) & BritP 522989(1940); CA **35**,4210 & 6114(1941) (AN coated with balsa woodmeal in the presence of w & granulated)
91)J.W.Dawson & W.M.Dehn, USP 2255653(1942) & CA **36**,272(1942) [AN, woodmeal, S, NG & hexachloronaphthalene(4-5%)]
92)M.A.Cook, CanP 411896(1943) & USP 2312752 (1943) & CA **37**,3943 & 4902(1943) [Expl blasting unit for oil-well shooting: AN (at least 50%),

PETN or Tetryl or TNT & $Ca(NO_3)_2 + NH_3$]
93)C.H.Winning, USP's 2314806-10(1943) & CA **37**,5241(1943) [Various blasting expls: AN, Al or NG & barley meal; AN, NG(not more than 25%), Al & rye flour; AN, NG or Al & spelt meal; AN, Na Nitrate,-chlorate or -perchlorate, NG or Al & oat flour; or AN, NG or Al & cereal meal(species Andropogon sorghum)]
94)R.W.Lawrence, USP 2325064-5(1944) & USP 2338120(1944); CA **38**,256 & 3478(1944) [Open -pit mining or quarry-blasting expls such as: mixt of AN, nitromethane & woodmeal or balsa (or bagasse); mixt of $HNO_3$ & nitromethane or other nitrated hydrocarbons; or AN, carbonaceous material, NG & one or several nitrated hydrocarbons]
95)R.W.Cairns, USP 2338164(1944) & USP 2355269 (1944); CA **38**,3478 & 6564(1944) [AN, $KNO_3$ or $NaNO_3$, pine-wood resin(petroleum insol) & NG]
96)W.deC.Crater, USP 2340304(1944) & CA **38**, 4134(1944) (Inositol Hexanitrate, NG, carbonaceous material & oxidg agent)
97)S.B.Watt & N.W.Adolph, USP 2344840(1944) & CA **38**,3842(1944) [AN, 60-89, NG(contg 0.05% NC) 3-5, $NaNO_3$ 2-20 & Al powd 1-2%]
98)J.Whetstone & ICI, BritP 552645-6(1944) & CA **38**,4134(1944) [TNT(emulsified), AN & $Ca(NO_3)_2.4H_2O$ or $NaNO_3$]
99)D.G.Morrow, USP 2355817(1944) & CA **39**,194 (1945) (Quarry, open-pit metal mining & military blasting expl; liq $N_2O_4$ & $CH_3NO_2$, $C_2H_5NO_2$, $C_3H_7NO_2$ or $C_4H_9NO_2$ proportioned to give an O balance betw -25 & +25%)
100)C.O.Davis, USP 2356149(1944) & CA **39**,194 (1945) (AN or $NH_4ClO_4$, woodpulp & S or Al & TNT prepd in block form)
101)C.O.Davis et al, USP 2362617(1944) & CA **39**,2880(1945) [Deton vel of blasting gelatin is greatly enhanced by incorporating one of the following compds(preferably 100 mesh): 0.4-2% Mn, Cu, Ti, Pb, Sn, Al or Fe(trivalent) oxide or 0.05-5% of the hydroxide or normal or basic salt of Pb, Fe or Al]
102)L.N.Bent, USP 2362878(1944) & CA **39**,2880 (1945) [Liq nitric ester(NG), carbonaceous material & $Ca(NO_3)_2$]
103)C.D.Bitting & R.W.Lawrence, USP 2365170 (1944) & CA **39**,3936(1945) [Cellular carbonaceous material(such as cork, balsa, bagasse, etc), hardened in situ with a synth thermosetting resin & satd with NG]
104)E.I.duPont & C.O.Davis, BritP 5646027(1944) & CA **40**,3606(1946) [Coal blasting expl: AN & oxidg material imbedded in a matrix of AN, compn free from NG; and a detong expl: AN, combustible carbonaceous material(such as S, woodpulp, vegetable meal, rye flour or flaked cornmeal) & NG absorbed in the blended granules]
105)C.D.Bitting, USP 2395367(1946) & CA **40**, 3606(1946) [Permissive expl for coal mines: pelleted mixt of AN, binding agent & NG(5-15%)]
106)J.Barab, USP 2398071(1946) & CA **40**,4218 (1946) (AN, DNT or mineral oil & coal or carbon-black)
107)C.H.Winning, CanP 435456(1946) & CA **40**, 6818(1946) (AN, with NG 3-25 & barley meal not over 0.15%)
108)C.S.Hallet, BritP 575147(1946) & CA **41**,4312 (1947)(Expl less susceptible to extreme temp than dynamite: NG & a small amt of $NH_4$ trinitrocresylate)
109)C.D.Bitting & R.W.Lawrence, USP 2433417 (1947) & CA **42**,7045(1948) (An expl consisting of NG, NC, $NaNO_3$ & woodpulp is improved in its ability to fire under high liq press or after long immersion in w, by incorporating ca 3% cornmeal impregnated with 25% of a heat-hardenable urea -$CH_2O$ or phenolic resin)
110)E.Whitworth et al, BritP 591755(1947) & CA **45**,862(1951) [Low-density blasting expl: solid salts, NG & NC(stabilized, with N content below 12.3% & not swellable by NG)]
111)R.J.W.Reynolds et al, BritP 593163(1947) & CA **42**,9180(1948) [Sens to deton of blasting gelatin on storage is prolonged by incorporating 0.05-0.50% of a so-called "NC crosslinking agent" such as hexakis(methoxymethyl)-melamine, bis(butoxymethyl)-urea, hexamethylene diisocyanate or N,N'-bis(hydroxymethyl)-adipamide]
112)E.Whitworth & J.C.Hornell, BritP 595443 (1947) & CA **48**,6699(1954) [Low d blasting expl suitable for use in gassy or dusty mines: 80/20 -NG/NGc 6-12, peat 7%, NGu 10, AN(0.8 bulk d) 57-59, resin 0.5, $(NH_4)_2HPO_4$ 0.5 & NaCl 11-17%. This expl of bulk d 0.73-0.76 is particularly useful in obtaining lump coal]
113)J.Whetstone & J.Taylor, BritP 597716&8(1948) & USP 2548693(1951); CA **42**,4349(1948) & **45**, 10590(1951) [AN 50, urea 25, Na acetate trihydrate 15 & $Na_2S_2O_3.5H_2O$ 10ps are mixed and heated to form a liq; 80ps of this liq are mixed with 20ps NG(contg 1% NC) to form a gelatinous expl. Another mixt contains: AN 34 & $Ca(NO_3)_2.4H_2O$ 66ps gelled by addg cornstarch 16ps & heating to 90° for ½hr]
114)H.R.Wright & W.G.Allan, USP 2439328(1948) & CA **42**,4350(1948) (Plastic expl: PETN or HNMnt & RDX distributed in a mixt of dinitrocumene, dinitro-tert-butylbenzene & the di-

nitration prod of sec-butylbenzene)
115)"Montecatini"SGIMC, ItalP 433633(1948) & CA **44**,1709(1950) (RDX 75 & Nitroisobutylglycerol tri acetate 25%, melted at 80°)
116)PGS, ItalP 433636(1948) & CA **44**,1709(1950) [TNT 30-90, RDX 5-65 & powd metal(Si,B,Mg,Cu, Fe,Al or Zn) 5-30ps]
117)E.Whitworth & J.C.Hornel, USP 2470733(1949) & CA **43**,5594(1949) (Blasting expls are stabilized by addn of approx 1% of a neutral mixt of alk metal dihydrogen orthophosphate & dialkali metal hydrogen orthophosphate)
118)J.Taylor & O.A.Gurton, USP 2481795(1949) & CA **44**,840(1950) [Blasting expl for gassy or dusty mines: AN 48.6, $NH_4Cl$ 21.3, limestone fines 20.1 & expl jelly [99%NG/EGDN(80/20) & 1% NC (11.95-12.25%N)] 10%]
119)PGS, ItalP 445206 & ItalP 445601-3(1949); CA **45**,1770 & 3160(1951) (TNT 30-90, PETN 5-65 & Al 5-30%; TNT 15-45, DNN 15-45, PETN 5-65 & Al 5-30%; or TNT 15-45, DNN 15-45, RDX 5-65 & Al 5-30%)
120)G.A.Lyte, USP 2499321(1950) & CA **44**,4680 (1950) (An expl relatively insens to impact & friction but initiated by a No 1 detonator: AN 50-68, PETN 3-10, TNT 4-15, $NaNO_3$ 7.5-25, mineral oil 0.4-0.7 & Al pdr 2-2.5%)
121)S.H.Davidson et al, BritP 645039(1950) & CA **45**,4043(1951) (AN blasting expl is improved in resistance to w damage by incorporating in the mixt a water-sol methylcellulose)
122)J.Taylor, USP 2548688(1951) & CA **45**,10590 (1951) [NC(moistened with an alc soln of eutectic AN & urea) & NG to give a non-tacky soln, w/o the desensitizing effect of water-dampened NC]
123)H.H.Fassmacht & C.A.Woodbury, USP 2548880 (1951) (Gelatinous expl: DNT 10, TNT 4, MNT 5, RDX 77, NC 1 & Tetryl 3%. Prod has d 1.58 and vel of deton 7000-8000 m/sec and is substantially less sens to shock than std gelatin dynamite) (*Note*: This mixt is same as RDX Comp C-3)
124)S.Fordham, USP 2554179(1951) & CA **45**,7345 (1951) [Blasting gelatin: NG 91.4, NC(contg 2% sulfonated methyl oleate) 8 & $CaCO_3$ 0.6%]
125)S.Fordham, USP 2554180(1951) & CA **45**, 9863(1951) [Blasting gelatin: NG & NC(contg 28% w & 0.4% isopropylnaphthalene sulfonate)]
126)Etat Français, FrP 980021(1951) & CA **47**, 7779(1953)[NC 30-40, $NH_4ClO_4$ 40-15 & AN 20-5 dried to a moisture content of 17%, malaxated (softened & mixed) at 80-85°, and sieved, after drying, to 1-2-mm particle size]
127)J.Taylor et al, BritP 670453-4(1952) & CA **46**,10625(1952) [Gelatin blasting expl for use under hydrostatic press of 40atm: NG & EGDN (80/20) 57.5, NC 2.4, woodmeal 10, $NaNO_3$ 24-8, finely milled barytes 5 & chalk 0.3%; for seismic prospecting & for well blasting: NG & EGDN 80/20) 57.5, NC 2.5, deproteinized, de-oiled peanut meal(16/100 BSS screen) 13, $NaNO_3$ 26.4, chalk 0.3 & $(NH_4)_2HPO_4$ 0.3%]
128)C.D.Goodale, USP 2615800(1952) & CA **47**, 2487(1953) (AN expls are made less hygro & less w-sol by coating them with 0.1-5% of 2,2-Dinitropropane combined with 5-30% of a non-volatile liq; the sens & performance of the expl is maintained during storage)
129)J.Taylor, BritP 682209(1952) & CA **50**,11672 (1956) (Low-density safety blasting compn: 80/20 NG/NGc 10, peat 12,AN 55.5, $NaNO_3$ 10, dendritic NaCl 12, $(NH_4)_2HPO_3$ 0.2 & rosin 0.3%. This compn has a packing d of 0.62, a rate of deton of 1450 m/sec and a power 59% that of blasting gelatin)
130)K.Hino & J.Sato, JapP 6196(1953) & CA **48**,11790(1954) [Colloidal expl: NG 9, NC 1, AN 52.5, urea 8, $CO(NH_2)_2.HNO_3$ 24.2 & HN:C-$(NH_2)_2.HNO_3$ 5.3%]
131)J.Santo, JapP 296(1954) & CA **48**,13222(1954) ($NH_2CONHNO_2$ 35-60, AN 20-40, NG 3-20 & urea 1-5%)
132)A.Sato,JapP 988(1954) & CA **48**,14210(1954) (NG 0-10, AN 60-45, RDX 15-20 & hydrated potter's clay 25%)
133)T.Sakurai,JapP 989(1954) & CA **48**,14210(1954) (NG 0-10, NC 0-05, AN 35-60, carbohydrate 0.5-5, w 5-15, NaCl and seaweed 5-25 & woodpowd & starch 0-10%)
134)N.Sakurai,JapP 990(1954) & CA **48**,14210 (1954) [Water(8%) is added to a mixt of Na cellulose glycolate 0.8, glutenous rice powd 2.5, glutenous millet powd 2.5, nonglutenous rice powd 3.0, flour 3.5 & potato starch 4.5ps. This compn (8.8-12.5%) is added to 87.5-91.2% of a mixt of NG 22, NC 1, AN 66.2 & woodmeal 2ps]
135)H.R.Wright et al, BritP 713758(1954) & CA **49**,3537(1955) [Improved gelatin blasting expl: p-tert-octylphenyl diethyl phosphate 0.20 & o-$CH_3C_6H_4NO_2$ 3ps are dissolved in 21ps of a nitrated 80/20 mixt of glycerol & $(CH_2OH)_2$, NC 1.1 added and then AN 56.9, $NaNO_3$ 12.0, oat husk meal 2.0, waxed woodmeal 0.5, woodmeal 1.0, S 2.0, starch 0.5 & chalk 0.3ps. The plastic props of the expl are lost if the phosphate ester is omitted]
136)G.Kuhn & A.Berthmann, GerP 903186(1954) & CA **52**,10581(1958) [Safety expl mixts contg 10% expl oil & 90% $NaHCO_3$/NaCl have little

power, while mixts with more expl oil are not safe. The expl oil content can be increased to 17-18% w/o sacrifice of safety by addn of 4-5% $Al_2O_3$ hydrate or $Fe_2O_3.3H_2O$. These substances absorb the expl oil and produce w upon deton, which cools the reaction products. The combination of these two effects makes the additives superior to Glauber's salt, talc or $SiO_2$]

137)SGEC, FrP 1075474(1954) & CA **53**,5678(1959) (Safe, water-resistant, insens, nontoxid expl for use in presence of firedamp: AN 84.5, DNT 14.6, & NC 0.9% mixed in a kneading mill. The somewhat gelatinous prod of loading d 0.91-1.34g/cc has a rate of deton 5250m/sec, temp of expln 2030° & is insens to a No 6 detonating cap. After 1 hr immersion in w, the cartridges are insensitive to a No 8 cap)

138)SNF, FrP 1081803(1954) & FrAddn 66511(1957); CA **53**,5678 & 2080(1959) [Mining expl for use in gassy mines: mixt of ground,foamed urea-HCHO resin/NaCl(45/55) 12, NG 11.5, NC 0.5, AN 53, NaCl 14 & $NaNO_3$ 9ps; or urea-HCHO resin-NaCl foam 47, gelatinized NG(1/40) 23 & $NH_4NO_3$ 30ps]

139)L.F.Audrieth, USP 2704706(1955) & CA **50**, 8208(1956) (AN 78.5-83.5, $N_2H_4.HNO_3$ 5-10, TNT 7.5, Al dust 0.5, coal pdr 0.3 & chalk 0.5%)

140)A.O.Franz, USP 2708623(1955) & CA **49**, 14326(1955) (Expl for deep-well oil operations: Pb salt of EDNA or in combination with other heat-stable proplnts. This compd does not explode spontaneously below 300° and is relatively powerful alone)

141)Wm.H.Rinkenbach, USP 2709130(1955) & CA **49**,14325(1955) [Blasting expl mixts of 1,1,1-Tris (hydroxymethyl)-ethanetrinitrate 50-85 & 2,2-Dimethyl-1,3-propanediol dinitrate 15-50% are claimed to have lower fr ps & shock sensitivity, and to be more viscous and stable than mixts of NG & NGc]

142)G.P.Sillitto & A.Butchart, USP 2711948(1955) & CA **49**,12834(1955) [Gelatin Blasting expl which eliminates NC dust and the possibility of ignition by accidental electrostatic discharge is prepd by mixing 21ps wet NC(Nca 12.5% & $H_2O$ ca 8%) with 75.5ps AN, 3ps glycerol & 0.5ps oleic acid]

143)S.H.Davidson & G.P.Sillitto, USP 271366 (1955) & CA **49**,12834(1955)[Gelatin blasting expl of reduced noxious gases & reduced eye and throat irritation suitable in hard-rock tunnelling: NC 0.9, 80/20 NG/EGDN 25.5, o-MNT 4.0, woodflour 2.5 AN 62.8, $CaSO_4$(anhydrite) 2.0 & urea 2.0ps]

144)J.E.Williamson, BritP 724060(1955) & CA **49**,14325(1955) (A nondetong, gas-generating blasting assembly suitable for use in fiery or gassy mines and having improved thermal and storage stability: $Mg(NO_3)_2.6H_2O$, AN & woodflour. Elec fuses of BkPdr or a GuN mixt are used to ignite the chge)

145)Etablissements John Kinsmen, FrP 1084121 (1955) & CA **53**,5678(1959)[Mining expl: AN(40-mesh) 86, $Sb_2O_3$(300 mesh) 4 & MgFe silicide 10%]

146)C.O.Davis et al, USP 2752848(1956) & CA **50**,13444(1956) [NG-free blasting compn: AN/$NaNO_3$ mixt(contg 30-85% AN) 60, DNT/TNT mixt(1-50% DNT) 10-30 & Fe silicon(contg at least 40% Si) 0.5-10%. This compn has a packing d of 1.3-1.5 g/cc, may be initiated by a cap-sens primer to give a deton vel of 3500-3900m/sec and has the same blasting strength as tamped dynamite. It is less toxic, much less shock-sens and forms more rigid cartridges than std Dynamite]

147)J.Taylor & T.J.Reid,BritP 743710(1956) & CA **50**,14230(1956) [Safety blasting expl: AN 53.1 & 11.9ps TNT are ground together and mixed with NaCl(thru No 60 sieve) 35ps. This compn has a vel of deton of 2400 m/sec and is initiated by a No 3 coml MF detonator]

148)D.L.Kouba, USP 2759807(1956) & CA **51**, 719(1957) (Semi-gelatinous expl: NG or NG+NGc 10-40, aromatic nitrocompd 5-30, hydrogenated terphenyl 0.1-5, NC 50-80, inorg oxidg salt 50-80, carbonaceous material 1-12 & antacid 0.3-1ps)

149)S.H.Davidson, BritP 757554(1956) & CA **51**, 7722(1957) [AN (up to 95%) is coated with TNT, woodmeal & NaCl added, the latter as flame-suppressing agent]

150)S.H.Davidson & T.Balfour, BritP 761396(1956) & CA **51**,8438(1957) (AN 82, powd Al 1, bagasse 8 & NaCl 8ps. This compn has a d of 1.04, power 68% of that of Blasting Gelatin, and can be initiated by a No 5-detonator)

151)A.Berthmann et al, GerP 938594(1956) & CA **53**,1716(1959) [Blasting expl resistant to humidity AN(coated with 0.05% Tetryl or 0.04% Nitroisobutylglycerol) 79.5, NG 4, TNT 14, sawdust 2 & dye 0.5%]

152)W.Maxwell & O.A.Gurton, USP 2789043(1957) & CA **51**,9164(1957) [Blasting device constg of: *main chge*-AN 55.0-75.0, $Ca(OOCH)_2$ 45.0-25.0 & Ca stearate 0-0.5%; *discharge head* AN (contg 0.05% acid magenta) 65.0, $Ca(OOCH)_2$ 34.9 & Ca stearate 0.1%, packed in a tube in the center of which is imbedded a *fuse heating device*- GuN 60.0, $K_2S_2O_8$ 31.5, $Cu_2Cl_2$ 8.0 & petroleum jelly 0.5%, wrapped in fireproof manila paper and

provided with an elec actuator. The blast takes place in 4 sec when this device is used in a bore hole]

153)J.E.Dolan & P.B.Dempster, BritP 769210 (1957) & CA **51**, 11720(1957)(O-balanced blasting compn consisting of AN, an org sensitizing agent & $CaCO_3$)

154)J.Alexander, BritP 777136(1957) & CA **51**, 14266(1957) [Gelatin blasting compn: 80-20 NG/EGDN 31.0, NC 1.6, o-MNT 1.0, alc 0.3, woodmeal 0.5, AN 24.2, NaCl 21.8, finely milled barytes 20.0, chalk 0.3 & $(NH_4)_2HPO_4$ 0.3p. This expl is detonatable under hydrostatic press & is incapable of igniting flammable gases]

155)Dynamit A-G, BritP 781072(1957) & GerP 938595(1956); CA **52**,732 & 15071(1958) [Noncaking, water-resistant AN expl: nitrotoluenes 16.0, AN 81.7, woodmeal 2.0, argillaceous earth(nature of clay) 0.1 & dye 0.2. Addn of 1% Tetryl improves resistance to caking]

156)Wm H.Rinkenbach & W.J.Carroll,Jr, USP 2814555(1957) & CA **52**,4184(1958) (Safe dry expl: urea 16-21, AN 79-84 & kaolin or diatomaceous earth 1-3%. This compn is detonable by a No 16 cap and is equiv to 50% Dynamite)

157)Dynamit-AG, BritP 787387(1957) & CA **52**, 6795(1958) [Noncaking expl of good storage stability can be obtained by mixing $NaNO_3$(coated with 1% Tetryl dissolved in benz) 80, NG 4, TNT 14 & woodmeal 2%. Another expl contained a mixt of $NaNO_3$ & AN coated with Nitroisobutylglycerol]

157a)Dynamit-AG,BritP 788311(1957) & CA **52**, 7703(1958) [Expl compns obtained by mixing AN+NaCl with NG or NG/NGc. One or both salts are coated with at least one surface agent, up to 0.2% by wt of the salts. As coating agents can be used: Nitroisobutylglycerol, DNPh, Tetranitrodichlorodiphenylamin, Tetryl, HNDPhA, DNDPhA or silicone AK 100[a poly(dimethylsiloxane) having a viscosity of 100 centistokes]]

158)Poudreries Réunies de Belgique,SA, BelgP 553954(1957) & CA **53**,18487(1959) (Gelatinous or semi-gelatinous coal mine safety expl: expl oil 10, $SiO_2$ 1.5, $NaNO_3$ 53.47, $NH_4Cl$ 33.53 & atomized Ca stearate 1.5%)

159)SAEPC, FrP 1133089(1957) & CA **53**,20807 (1959) [Brisant coal mining expl device: *igniter chge*- AN 70-80, $NaNO_3$ 2-5, starch 1-5, cellulose 3-6, Ca stearate 0.05, $Sb_2S_3$ 0.01, S 0.05 & $KMnO_4$ 0.26% is activated by an elec bridge and develops sufficient press(80atm min) to dec the *main chge*- AN 60-75, cellulose 3-7 & $CaCO_3$ 10-20% which develops high gas press, suddenly released by failure of a rupture disc, thus loosening coal]

160)Poudreries Réunies de Belgique, SA, BelgP 555262(1957) & CA **53**,22955(1959) [Powd safety coal mine expl: TNT 12, AN 69.5, NaCl 17 & Ca stearate 1.5% (or Ca stearate 1.0% and carboxymethylcellulose 0.5%)]

161)F.Lazzari, ItalP 558412(1957) & CA **53**,719 (1959) (Gelatinized expl with stabilized sensitivity: NG/NGc 36, collodion cotton 25, AN 49.5, cellulose 1, TNT 6 & $PbSO_4$ 5ps)

162)I.Fukuyama & H.Miyasue, JapP 8298(1957) & CA **53**,3698(1959) [Low NG gelatin expl: AN crystd with 3% $KNO_3$) 75, NG gel(contg 2% NC) 10, starch & other combustibles 13 & $H_2O$ 2%]

163)Société Tunisienne d'Explosifs et de Munitions & P.Chaudron, FrP 1134326(1957) & CA **51**,10062 (1957) (Expl for seismic exploration: RDX or PETN 30% & AN 25% are dispersed in TNT)

164)A.Berthmann & G.Kuhn, GerP 1004983(1957) & CA **54**,13666(1960) (Blasting sheathed expl of increased flameproofness: *core expl*- gelatinous blasting oil 11, TNT 2, woodmeal 3, $NaNO_3$ 51.6 & $NH_4Cl$ 32.4%; and its *sheath*- blasting oil 10, $Al_2O_3$ 2 & NaCl 88%)

165)E.J.Russell, USP 2821466(1958) & CA **52**, 6795(1958) [Water-resistant semigel blasting expl; AN 72, $NaNO_3$ 3.5, NS 20, 1,1,1-Tris(hydroxymethyl) ethane Trinitrate 1, carbonaceous matter 3 & chalk 0.5%]

166)M.Scalera H M.Bender, USP 2826485(1958) & CA **52**,8560(1958) [Water-resistant blasting expl: NG 7.8, AN 75, $NaNO_3$ 4.3, NaCl 1.5, carbonaceous fuel 8.4 & polymeric mixt(methylenebisacrylamide 3, acrylamide 95 & $K_2S_2O_8$ 2%) 3%. This compn is 3-4 times as w resistant as a similar compn w/o the acrylamide mixt. An expl contg a copolymer of 10/90- acrylic acid/acrylamide 80 & $Al_2(SO_4)_3$-$7H_2O$ 20% also shows excellent resistance]

167)A.Berthmann & G.Kuhn, USP 2829036(1958) & CA **52**, 10581(1958) [Fire-damp-proof expl: $NaNO_3$(32% <0.1mm) 56.8, $NH_4Cl$(22% <0.1mm) 35.7, NG 4.2, NGc 2.8 & argillaceous earth(clay) 0.5% gave a Pb block expansion of 79cc. Another mixt: $NaNO_3$(80% <0.1mm) 54.6, $NH_4Cl$ (80% <0.1mm) 34.4, NG 6.3, NGc 4.2 & argillaceous earth 0.5% gave a Pb block expansion of 81cc. Both expls were safe with a max chge of 16 cartridges in a single shot mortar against $CH_4$ -air mixts]

168)T.Sakurai, USP 2847291(1958) [Gelatin expl: AN 57.1, $KNO_3$ 5, carbonaceous fuel 7.8, NC gel 22-30 & konjak mannan gel(contg 8-12% $H_2O$) 8ps]

169)W.Taylor et al, BritP 797112(1958) & CA **53**, 1716(1959) [Expl for blasting under wet conditions

or in strip mining of coal, rock or metal: AN(coated with 4% mineral jelly) 92 & Al powd 4ps mixed at temp of 60-70°. This compn detonates in air at 3200m/sec and in cartridges possesses 87% the power of Blasting Gelatin; it is detonatable after immersion under 10ft of w for 1 hr]
170)N.Nakashiro & K.Takizawa, JapP 5849(1958) &CA **53**, 16540(1959)[Colloidal expl: NC(ca 12%N) is immersed in a dil aq soln of starch(or other paste-forming agents) & mixed with 1/1 NG/NGc]
171)G.L.Griffith,Jr & D.G.Samuel, Jr, USP 2680041 (1958( & CA **53**,3697(1959) [Blasting expl claimed to be relatively insensitive and nonhazardous are obtained by mixing AN & NS with other ingredients. Eg: AN 51.8, Na nitrate 16.1, Al pdr 2.7, Na carboxymethylcellulose 1.0, pecan meal 1.0, petroleum oil 0.4, ZnO 0.3 & NS(contg 20% w) 33.4ps are thoroughly mixed to produce an expl of high strength]
172)J.E.Lambert & I.O.Lewis, BritP 810045(1959) & CA **53**,10765(1959) [Blasting chge for use in vertical boreholes: AN 86.5-94.6, Al pdr up to 7.5 and meal up to 4% are introduced into the borehole and a nonexpl liq fuel (such as paraffin oil or MNT) is added. The expl mixt is detonated with a primer cap]
173)N.A.R.Bell & D.Storer, BritP 810046(1959) & CA **53**,10765(1959) [Blasting chge for vertical boreholes consists of a 2-in core of HE's mixt (such as NG, NC, woodmeal & waxed woodmeal) in a cardboard container is surrounded by a sheath of AN, 6" in diam]
174)C.J.Breza, USP 2861875(1958) & BritP 821499(1959); CA **53**,4740(1959) & **54**,3957(1960) (Blasting expl: AN 27, $NaNO_3$ 72, Fe silicon 24, stearic acid 0.5, TNT 23.2 & DNT 3.3ps mixed at 175°F and cast)
175)Poudreries Réunies de Belgique, SA, BelgP 573923(1959) & CA **54**,3957(1960).[Safety coal mine expl: expl oil 10, kieselguhr 1.5, $NaNO_3$ 54.5, $NH_4Cl$ 32.5, 75/25- polyethylene glycol/carboxymethylcellulose 1.0 & stearinated chalk 0.5%]
176)D.E.Pearsall, USP 2909418(1959) & CA **54**, 5090(1960) [O-sufficient combustible mixt for blasting & other applications: $BaO_2$ 79.5, $KNO_3$ 5.6, Si 5.6, C(furnace black) 2.8, NC 6.0 & Al stearate 0.5%, on blending with vol esters or ketones, drying, granulating and coating with graphite, burns like BkPdr]
177)Commercial Solvents Corp, BritP 824533(1959) & CA **54**,8087(1960) [Safe blasting expl, with O balance -15 to +15%, which can be prepd at the site: AN 95, nitromethane(NMe) 4.5 & $(CH_3)_2C(NH_2)CH_2OH$ 0.5 gives an O balance +15.75; AN 60, NMe 36 & $(CH_3)_2C(NH_2)CH_2OH$ 4% gives -14.0; AN 95, β-nitropropane 4.5 & $(CH_3)_2C(NH_2)CH_2OH$ 0.5% gives +11.5%; and AN 80, β-nitropropane 18 & $(CH_3)_2C(NH_2)CH_2$-OH 2% gives an O balance of -14.9%]
178)Manufacture Générale de Munition, FrP 1184312(1959) & CA **54**,20210(1960) (In expls intended for seismic prospecting, propagation of NG is facilitated by the introduction of small hard inert particles, such as sand, Fe filings, crushed rock or corundum. Eg: NG 32.8, NC 1.3, AN 51.2, cellulose 3.8, $BaSO_4$ 4.7 & sand 6.2%)

**Blasting Explosives, Ammonium Nitrate.** See Vol I,p A341

**Blasting Gelatin(Dynamite Gomme A, Sprengelatine, Gelatine Explosive)** [See also Vol I, p A147(table)]

This is one of the most powerful coml expls. It was invented by A.Nobel in 1875 and is still used extensively. It is prepd by gelatinizing 92-93ps NG with 8-7ps collodion cotton(N 11.1 to 12.5%) either by warming the ingredients(to 60-70°) in a water-jacketed vessel or by adding solvs, such as acet or ether-alc, to facilitate the gelatinization. Approx 0.2% of $CaCO_3$ is added as an antacid and about 0.3% moisture is usually present in blasting gelatin. Lab prepn is given in Ref 1(p 226). The resulting gelatin is stiff and semi-transparent. This expl contains more NG than any other and does not contain any inert ingredients except 0.2% $CaCO_3$

The following props are given in Refs 1 & 3: *Brisance*(Kast's method)- 148 x $10^6$(86 x $10^6$ for TNT) or 172% TNT(Ref 1,p 95); *Heat of Explosion*- 1610 cal/g at $C_v$ and $H_2O$ vapor; *Power*- by Trauzl Test 520 cc(TNT 285) or 182% TNT(Ref 3); *Specific Energy*- 12,285(TNT=8,080) or 152% TNT(Ref 3); *Specific Volume*(Volume of gases of explosion at 0°/760mm)- 711 l/kg(TNT=690)

According to Berthelot, the equation for the combustion of blasting gelatin containing 91.6% NG and 8.4% collodion cotton is as follows:

$$51C_3H_5(NO_3)_3 + C_{24}H_{31}O_{11}(NO_3)_9 = 177CO_2 + 143H_2O + 81N_2$$

*Temperature of Explosion*- about 4450°(calcd) (Ref 1,p 87); *Vel of Deton* at d 1.63,7500-7800 m/sec. *Diminution of Sensitivity of Blasting Gelatin.* This expl in storage progressively hardens with age and this is accompanied by a diminution of sensitivity to initiation and by a considerable decrease in power as detd by Trauzl Test. If stored for a long time the gelatin may misfire. Such a gelatin can be "revived" by heating it on

a water bath(to about 60-70°) and then cooling. Another method consists of prolonged rolling of the cartridge on a flat surface(Ref 9a). This phenomenon of stiffening of gels with time is common but is not yet fully understood. Two theories are briefly discussed under Ageing of Dynamites in Vol 1,p 111-L

*Refs*: 1)Marshall 1(1917), 365-8 2)Naoûm NG (1928),11 & 283-323 3)Vennin, Burlot & Lécorché (1932),552-3 4)Sukharevskii & Pershakov(1932), 150 5)Stettbacher(1933),87,95 & 225-6 6)Pepin Lehalleur(1935),328 & 324 7)Davis(1943),334 8)Bebie(1943),35 9)C.H.Johansson & A.Persson, ApplSciRes**A4**,295-304(1954) & CA **48**,11789(1954) (Rate of burning of blasting gelatin at different temps & press) 9a)Dr I.A.Grageroff; private communication(1955) 10)Cook(1958),9

**Blasting Gelatin, Antifume.** See Vol 1,p A466-L

**Blasting Initiators(Caps), Electric.** See under Blasting Cap

**Blasting Machine**(called Zündmaschine in Ger). A device designed to supply current for firing elec blasting caps. The device consists of a wooden or metal case which encloses either a magneto or generator. The generator is driven by a gear mechanism activated by either a plunger or a shaft extending from the top of the case. By pushing the plunger(or twisting the shaft) the magneto or generator is made to rotate, developing 110-300 volts of either alternating or direct current. The current is transmitted to a series of caps(as many as 100) by means of leading wires and the chges of blasting expls are thereby detonated. The plunger-type machines are called Push-Down Blasting Machines.

In large permanent operations, firing is sometimes done with current supplied by batteries or by special electrical circuits connected to regular power lines

*Refs*: 1)Meyer(1943),334-5 2)Anon, "Ammunition Inspection Guide", TM **9-1904**(1944), 762 3)F.C. Gibson & F.W.Brown, US BurMines RI **4136**(1947) 4)Blasters' Hbd(1952),106ff 5)Anon,Explosivst **1954**,127-8(Blasting machine with millisec delay)

**Blasting Oil.** The name given to NG by A.Nobel. It is also called *Explosive oil*

*Refs*: 1)Bebie(1943),36 & 108 2)Cook(1958),8

**Blasting Powder "A"** A $KNO_3$ BkPdr prepd in grains of various sizes. The use of $KNO_3$ makes this powd considerably faster, slightly stronger, and less hygr than $NaNO_3$ powders, but it is more expensive. It is used principally in quarrying fine dimension stone, granite and slate where the shattering effect of dynamite is undesirable. This powd is also used in the manuf of fireworks and fuses

*Refs*: Bebie(1943),36

**Blasting Powder "B".** A $NaNO_3$ BkPdr the grains of which are glazed with graphite to render them more moisture-resistant. It is slower, less powerful, more hygr and less expensive than Powder "A" and is used extensively for blasting purposes in non-gaseous coal mines, in stripping operations and in clay and shale

*Refs*: Bebie(1943),36

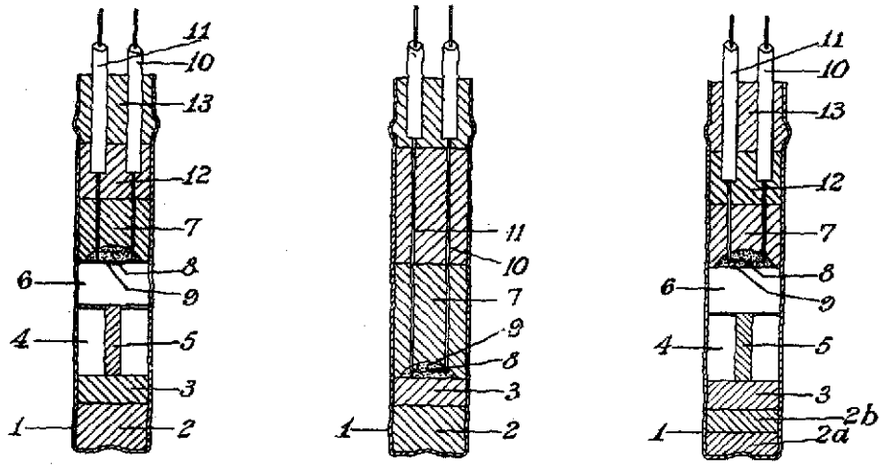
**Blasting Powder, Black** See under Black Powder

**Blasting Soluble Nitrocellulose.** The same as Collodion Cotton, It is used in blasting expls for gelatinizing NG

**Blasting Squibs, Electric.** Elec squibs are devices useful in igniting deflagrating expls(such as BkPdr), where the nature of the expl is such that it is desirable to fire the chge by means of a flame, as distinguished from dynamites and other high expls, which are initiated by the deton of expls contained in ordinary elec caps(see under Blasting Initiators)

The modern elec squib generally consists of an ignition chge enclosed in a shell or tube of metal or plastic and an elec firing device. This device consists of two leading(leg) wires, passing through a mass of insulating material which closes the end of the cap, and are connected within the cap by means of a highly resistant wire(bridge) of such diam that it is heated to incandescence when the elec current passes through it. The bridge wire is surrounded(embedded in, or cemented in) by the "ignition composition"(see below) so that passage of the current through the wire causes the "ignition composition" to ignite, which in turn causes the deflagration of the priming chge. When the squib is thus fired, the flame plays upon the blasting expl outside the squib

In the ordinary elec squib, the lower end of the shell may be either open or perforated to allow the escape of the flame on ignition. In order to prevent the access of moisture inside the squib a stopper is sometimes provided to close the ventholes. This stopper is removed just before




**ELECTRIC BLASTING SQUIBS**

1 – Ventless metal shell
2 – Base charge
2a – Lower base charge
2b – Upper base charge
3 – Ignition charge
4 – Metal carrier (tube)
5 – Delay composition
6 – Chamber
7 – Concave plug
8 – Bridge wire
9 – Electrical firing element (powd chge)
10 – Leading wire
11 – Leading wire
12 – Waterproof layer
13 – Sulfur seal

the squib is used. Even with stoppers, these squibs are susceptible to the action of moisture. This is particularly undesirable in the so-called *delay squibs*(see Note below) because admission of moisture through the vent may cause the delay column to be damped out or to burn non-uniformly, thus rendering an entire round of shots unsatisfactory due to deviation from the calculated delay periods of one or more squibs in the group

*Note*: Delay elec squibs differ from ordinary elec squibs in that the firing element is separated from the chief deflagrating chge by a column of material having a uniform rate of combustion and serving as a delay element

Burrows & Noddin of the DuPont Co (Ref 2) proposed using a ventless(closed) squib, although previous attempts to produce such squibs[eg, that of Lewis & Woodbury(Ref 1)] were not successful. Instead of providing the shell with weakened portions of wall in the region containing the chge to insure rupture of the shell at such points of ignition, as was previously done, Burrows & Noddin provided the base of the cap with a vent sealed with a disc of metal melting at the temp developed on ignition of the base chge in the cap. As the temp of ignition of the base chge should be fairly high, special mixts were designed, such as those containing finely divided Mg & Ba peroxide or selenium, barium hydroxide & nitrostarch

The table on the following page gives examples of squibs proposed by Burrows & Noddin:

Instead of the base chges listed in the table, the following other combinations may be used: a)Combination of one of the powd metals, such as Zn, Cr, Cd, Fe, Co, Ni, Pb, Cu, As, Bi or Sb with oxidizers, such as permanganates, perchlorates, perborates, persulfites, peroxides, chlorates, bromates and iodates; b)combination of Mg or Al with cyanides, phosphates, carbonates, sulfates, etc

In addition to the ignition agents listed in the table, the following may be used: Se and $BaO_2$ with either BkPdr, ground smokeless powder or Turnbull's Blue; zirconium with $BaO_2$ or BkPdr+ NC(ca 12.7%N) + NS

It has been claimed that the squibs listed in the table are safe to handle and transport because they are insens to impact and if accidently

| | No 1 | No 2 | No 3 |
|---|---|---|---|
| *Base Charge* | 9 grains powd $BaO_2$ 87.5 + metallic Mg 12.5 | 10 grains powd CuO 75 + Mg 25 | *Lower base chge* 4 grains $BaO_2$ 88 + Al 12% *Upper base chge* 4 grains $BaO_2$ 93 + Al 7% |
| *Ignition Charge* | 3 grains $BaO_2$ 78 + Se 19 + nitrostarch 3% | 3.5 grains $BaO_2$ 92 + nitrostar ch 8% | 2.5 grains $BaO_2$ 78 + Se 19 + NS 3% |
| *Delay Powder* | $BaO_2$ 85 + Se 15% | No delay element, so that the ignition chge is in direct firing relation with the ignition compn surrounding the bridge wire | $BaO_2$ 85 + Se 15% & traces of inert material |
| *Concave Plug Powder*(surrounding the bridge wire) | MF 51 + $KClO_3$ 23 + NS 9 + charcoal 17% | MF 38.5 + $KClO_3$ 38.5 + NS 15.3 + charcoal 7.7% | MF 51 + $KClO_3$ 23 + NS 9 + charcoal 17% |

ignited, they burn w/o producing an explosion

In a later patent(Ref 3), Burrows & Van Winter of the DuPont Co proposed some modifications in delay elec squibs in order to prevent misfires when fired in series. The inventors claimed that misfires in series may be practically eliminated by selecting a bridge wire so characterized that the time required for its fusion is sufficiently greater than the period of initiation of the chge that certainty of firing in series is assured. For the bridge, it was proposed to use wire of about 0.0025" diam made of an alloy of Ni 80, Cr 20(instead of a wire 0.0015" diam composed of an alloy of Pt 80, Ir 20, as is customarily used. Although the Ni-Cr wire is satisfactory for any squib, it solves the specific problem for a squib containing an ignition chge capable of initiation by elec means, but which undergoes initiation so slowly that misfires occur(when the Pt-Ir bridge is used) when such chges are fired in series. Especially effective is Ni-Cr wire when the so-called"*slow ignition charge*" is used which is explained by the inventors as "an ignition charge capable of being initiated by means of a standard Pt-80-Ir-20 bridge wire of 0.0015" diam but which undergoes initiation so slowly that misfires occur when such charges are fired in series by means of such wires"

Other inventors state that the use of wire which is slow to fuse is particularly advantageous when employed in a squib having an ignition chge comprising a loose blend of ground smokeless powder 60 and BkPdr 40. A firing current of 0.330amp was found suitable for firing such ignition mixt. The same wire was also found suitable for firing many other slow ignition mixts, such as ground smokeless powd with a least one oxidizing agent such as $KClO_3$, $KNO_3$, $Ba(NO_3)_2$, $BaO_2$ and at least one finely divided metal(such as Al, Te, Se, Zr, Mg, etc). Sulfur & Ca silicide may be substituted for the metals mentioned above

*Refs*: 1)H.A.Lewis & C.A.Woodbury, USP 1964826 (1934) & CA **28**,5242(1934) 2)L.A.Burrows & G.A.Noddin, USP 2123691(1938) & CA **32**, 7268(1938) 3)L.A.Burrows & C.B. Van Winter, USP 2228339(1941) & CA **35**, 2722(1941) 4)Blasters' Hdb(1952), 92

**Blastite.** A coml expl invented by Rosslyn & manuf in Scotland in 1895, consisted of NC, glycerin & vaseline

*Ref*: Daniel(1902),74 & 694

**Blast Meters.** The measurement of air blast or blast effects created by shock waves is made by blast meters of various designs. Prior to WWII one type of blast meter consisted of a board provided with holes of different diameters across which were pasted pieces of paper. In this so-called

"paper blast gage" the smaller the diam of the disc which is ruptured the greater the blast strength. Although this type of blast meter gives fairly accurate comparative results, it suffers from the difficulty of maintaining its calibration from one series of tests to another and from the variations of temp & humidity(Refs 1 & 6)

Various improvements in the design of air blast meters were made possible by the use of piezo-elec gages, tourmaline gages and Pb or Cu crusher cylinders with suitable electronic amplifying devices. It is possible with these devices to obtain complete detailed records of the shock wave and to compare peak press and impulse values of different expls. These blast meters are described in various refs(Refs 2,3,4,5 & 9a). Schmidt(Ref 9) discusses various experimental procedures used for measuring blast effects

Philipchuk(Ref 7) has reported the use of the *Pendulum Gage, Foilmeter, 5"NTC(National Tubular Compartment) Gage* & the *Catenary Diaphragm Gage* for the measurement of free-air blast from bare expl chges. Jefferys et al(Ref 10) used the *H3 Blast Gage* for the measurement of air blast. The damage potential of air & ground blast waves and their measurements at long range are discussed by Cook(Ref 8)

*Refs:* 1)Maj A.W.Ford,ArOrdn **7**,222-4(1927) 2)A.T.Ireland, USBurMinesTechPaper **635**(1942) (Design of Air-Blast Meter and Calibrating Equipment),20pp 3)E.D.Wilson,Jr,OSRD Rpt **1153** (1943) 4)Anon,OPM **40-34**(1944) 5)S.Schulman, OSRD Rpt **5847**(1945 & PBL **50829** 6)W.A.Noyes, Jr,Ed "Science in WW II(OSRD), Chemistry", Little, Brown & Co, Boston(1948),84 7)V.Philipchuk, "Blast Evaluation of Bare and Cased Charges", Initial Phase Rpt NN-P-30, National Northern Co, West Hanover, Mass(1955) 8)Cook(1958),365ff 9)A.Schmidt,Explosivst **1959**,225-31 & **1960**,7-14 9a)Anon,OPM80-12(1959) (Air blast pressure measurements, electronic) 10)R.C.Jefferys et al, ARDE Memorandum(MX) 54/60, "The Measurement of Air Blast"(1960)

**Blast Wave or Burst Wave.** See under Blast Effects in Air

**BLB.** A cast double-base propellant developed at ABL. Its compn & props are in Conf "Propellant Manual"SPIA/M2(1959), Unit No 506

**BLC.** A cast double-base propellant developed at ABL. Its compn & props are in Conf "Propellant Manual"SPIA/M2(1959), Unit No 507

**Bleiazid**(Ger & Swiss). Lead Azide, described in Vol 1,p A545ff

**Bleitrinitroresorzinat or Bleistyphnat**(Ger & Swiss). Lead Trinitroresorcinate or Lead Styphnate, described under Resorcinol and Derivatives

**"Blend".** US military grade NC prepd by blending pyrocotton (N content 12.6-12.7%)and guncotton (N ca 13.4%). The resulting mixt contains 13.15± 0.5%N

Its prepn, props, tests & US Spec requirements are given under Nitrocellulose which is described under Cellulose and Derivatives

**Blenders.** See Mixing & Blending Equipment

**Blending.** See under Mixing, Kneading & Blending.

**Blending of Propellants.** See under Propellants

**Blindage.** (Fr) Armor; armor plate

**Blindé** (Fr).Armored; bullet proof

**Blindicide.** A Belgian antitank(A/T) rocket launcher similar to Amer Bazooka. It fires "Energa" rockets(see also under Belgian Explosives, etc)

*Ref:* E.Tomson, Liège and F.Lebrun, Bruxelles, Belgium; private communication(1961)

**Bloc de Plomb ou Bloc de Trauzl(Fr).** Lead Block or Trauzl(Block) Test. See Coefficient d'Utilisation Pratique(CUP or cup), Vol 1, p IX-X

**Blockbusters.** Very large(up to 20 or more tons) cylindrical bombs with extremely light case, strong enough to withstand handling and shipping, but so weak that no penetration is possible because the case breaks upon impact. Such bombs are of very high-capacity(ca 80%) and are fuzed for non-delay or superquick action. They must be dropped from medium to high altitude so that impact near the vertical is obtained, but without touching the target. Their action is based on **blast effect**(qv) alone and they are capable of damaging areas, particularly residential, as large as a block or even larger. That is why they are called blockbusters (Compare with Bombs, Earthquake)

*Refs:* 1)Ohart(1946),204 & 227 2)PATR**2510**

(1958), Ger 192(under Structural Explosives)

**Block Explosives.** Certain expls such as TNT, Tetrytol, RDX comps, NC & NS compns, when in the form of cast or pressed blocks, are called block expls. These blocks are usually used for demolition purposes
*Ref*: A.B.Schilling, PicArsn; private communication(1961)

**Block-Fitted Loading.** See under Loading of Ammunition

**Blockholing.** When it is necessary to remove boulders or rocks deeply buried in earth, either a "snake-holing" or "blockholing" method is used. Blockholing consists of drilling a hole about 1" in diam into the boulder(about half way), charging it with dynamite and blasting. Drilling may be done with a hand-held hammer(jack hammer). Blockholing is also used in "secondary blasting" and in blasting outcropping ledges, which are difficult to remove

The DuPont Co recommends the use of "Red Cross Extra", 20%, for blockholing
*Ref*: Blasters' Hdb(1952),pp 329ff & 359-360

**Blocking and Block Breaking.** Operations used in manuf of smokeless propellants
*Refs*: 1)Hayes(1938),22-4 2)TM **9-2900**(1940), 20-4 3)TM **9-1904**(1944),84

**Blomen** of Landing,NJ,USA, patented in 1893 an expl prepd by dissolving in NG a product obtd by the action of PA on an aromatic hydrocarbon
*Ref*: Daniel(1902),p 74

**Blood Pressure Lowering.** The hypertensive effect of several expl compds has been reported by Sallé (Refs 1,2,&3). Dinitroglycerol, NGc, bis(hydroxymethyl)nitroethane dinitrate, dimethylol nitroethane dinitrate, bis(hydroxymethyl)nitropropane dinitrate & dimethylol nitropropane dinitrate were studied. These compds were found to be vasodilators, less active than NG but excercising a more lasting effect(Ref 3). Nitrated sorbitol has a vasodilator effect similar to hexanitromannitol(HNMnt) but is sl more toxic than HNMnt(Ref 2)

The vasodilating props of some "new" nitro derivs was detd on small animals(Ref 3):
I. $O_3N.NH_2(CH_2CH_2ONO_2)_2$ [called di(β-nitroxyethyl)ammonium nitrate in Blatt; not found in CA index]
II. $O_2N.N(CH_2CH_2ONO_2)_2$ [called 2,2'-(nitroimino) diethanol dinitrate or bis(2-nitroxyethyl)nitramine in CA and diethanolnitramine dinitrate or dinitroxyethylnitramine(DINA) in Blatt]
III. $O_3N.NH_2(CH_3)CH_2CH_2ONO_2$ [called (β-nitroxyethyl)methyl ammonium nitrate by us; not found in CA Index nor in Blatt]
IV. $O_2N.N(CH_3)CH_2CH_2ONO_2$ [called 2-(methylnitramino)ethanol nitrate in CA and 1-nitroxytrimethylene-3-nitramine(MeNeNA) in Blatt] ]

Compds I,II & IV caused decreased blood press; III was less active and caused tachyphylaxis. No manifestation of chronic toxicity was observed with either I or II
*Refs*: 1)J.Sallé, Thérapie **8**,565-77(1953) & CA **48**, 5369(1954) 2)J.Sallé, ArchInternPharamacodynamie **98**,355-61(1954) & CA **49**,7115(1955) 3)J.Sallé,MP **36**,305-7(1954) & CA **49**,16218(1955)

**Blow.** The slang word for an expln, a severe deton or any expl type malfunction that occurs when testing a rocket thrust chamber or similar rocket component
*Ref*: Rocket Encycl(1959),52

**Blowback.** An escape of gas under press to the rear, on firing small-arms or fixed or semi-fixed artillery ammunition, is called a blowback. This may be caused by ruptured cartridge, pierced primer, primer leak, blown primer or primer set -back. The term also applies to the recoil of an unlocked bolt in a firearm
*Refs*: 1)TM **9-1910**(1955),p 231 2)Glossary of Ord(1959),39

**Blowcase.** See Acid Egg or Blowcase; Vol 1, p A88-l

**Blow Oil.** See Oxidized Oil

**Blown-out or Burned Shots.** If dynamites(or other expls) are not properly detonated, they burn slowly and incompletely in the borehole, resulting in so-called blown-out shots. Such shots are accompanied by the evolution of poisonous gases, such as nitrogen oxides, acrolein & carbon monoxide, which are very undesirable in underground mines. As such shots do very little useful work, care should be taken in prepg the charges to insure that the expl is properly primed with an initiator of sufficient strength to insure complete deton
*Note*: With properly detond dynamites, principally non-poisonous gases such as $CO_2$, $N_2$ & $H_2O$ vapor are evolved
*Ref*: Naoúm,NG(1928),pp279-80

**Blowout of Tracers.** When a tracer compn is not properly fixed inside the projectile cavity, the entire tracer might be ejected intact from its cavity shortly after leaving the muzzle of the gun. As such blown-out tracers usually catch fire, they might cause casualties among the firing gun crews
*Ref*: H.E.Hirschland & S.Ricklin, Ordn **32**,92(1947)

**Blue Cross Ammunition**(called Blaukreuz in Ger). The Germans, in grouping their chemical warfare gases, applied a combination of military & toxicological viewpoints. Gases of their first group, comprising the offensive gases(eg, tear gases) and the poisons causing such effects, were called "green cross gases" (Grünkreuz). These gases did not penetrate ordinary gas masks equipped with charcoal filters

When this protection became available, the need arose for such gases which could penetrate charcoal filters, thus forcing the enemy to remove their masks and inhale the gases of the first group, which were shot simultaneously with gases of the second group. This second group of gases was designated by a "blue cross" and the poisons causing irritating effects were called "blue cross gases". The prototype of these gases is diphenylarsinechloride. Protection against them, in the form of paper or cotton colloid filters, was almost immediately developed and made available to troops

The third group comprised the defensive gases or "yellow cross gases" (Gelbkreuz). These gases attained their purpose by persistency and, therefore, contaminated an area for a protracted period thus making it uninhabitable. The prototype of this group is mustard gas

The purpose in using "green cross", "blue cross" and/or "yellow cross" ammunition was to cause temporary incompacitation of the enemy personnel, either immedy or within a short time
*Ref*: C.Wachtel, "Chemical Warfare", Chemical Publishing Co, Brooklyn,NY(1941),99

**Blue Grass Ordnance Depot.** US Ordnance Corps field installation located near Richmond,Kentucky

**Bluff-Shaped Bomb.** A blunt-nosed bomb which approaches the configuration of a cylinder having enclosed end flanges of two different thicknesses. This configuration can be launched in a turbulent air region w/o tumbling and the bomb will not "float" or remain suspended as a result of its lack of "lift". Thus, a *false* bluff shaped outer configuration can be housed over a penetrating-type bomb, thereby overcoming bomb-bay release problems associated with tumbling or floating, and the bomb will still retain its penetrating effectiveness
*Ref*: A.Berman,Picatinny Arsenal,Private Communication(July 1961)

**Bluff-Shaped Munitions.** Discussed in Minutes,OCM (OrdComm Meeting),Item 361591(A-690),Project TA2-9111,26 April 1956(Conf)

**Bluff-Shaped Projectiles.** The static stability & drag characteristics of bluff, finless projectile and bomb shapes were discussed in a lecture by Loeb
*Ref*: A.A.Loeb,Testing Section Tech Lab Services Lecture,PicArsn,18 Sept 1956

**Blunderbuss**(Streubüchse in Ger, which means scattering or strewing gun). It is an obsolete gun or firearm having a short barrel of rather large diam(up to 3.5"), provided with a belled muzzle. It was capable of holding a number of balls and was intended to shoot objects at close quarters without exact aim

The weapons shooting several balls at a time were known as early as the middle of the 15th century but the gun resembling a real blunderbus was introduced in Spain in 1654 under the name "arcubus". This was a matchlock arm. The later models were provided with flintlocks and they were used as late as the 19th century. Some blunderbusses were used in the navies. For instance a number of blunderbusses were manufd in 1810 at the Harper's Ferry Armory for the US Navy(Ref 1)
*Refs*: 1)W.H.B.Smith, "Small Arms of the World", Military Service Publishing Co, Harrisburg,Pa( (1955),215 2)Glossary of Ord(1959),40

**BM Mixture.** A smoke screen mixt constg of Zn dust, $CCl_4$ and relatively small percentages of $NH_4Cl$, $NaClO_4$ & $MgCO_3$. Since this mixt is unstable it was replaced by a costlier HC Mixture (qv). Where long-time storage would not be necessary the BM mixt would be more economical than the HC mixt. These mixts were used in pyrotechnic candles, mortar shells & grenades
*Ref*: H.W.Walker,IEC **17**,1064(1925)

**BM Powder or Poudre BM.** French Naval Ordnance, Poudre B(M=marine=navy) made in the form of strips, the sizes of which varied according to gun caliber. See under B(Poudre), item k(this vol)

for designations $BM_1$ to $BM_{20}$ and other varieties
*Refs*: 1)Marshall **1**(1917),297 2)Pascal(1930),226

**BN Powder or Poudre BN.** A modified(new) French Poudre B(N=nouvelle=new) smokeless powd consisted of guncotton 29.1-38.7, collodion cotton 41.3-33.2, $Ba(NO_3)_2$ 19.0-18.7, $KNO_3$ 8.0-4.5, $Na_2CO_3$ 2.0-3.6 & vol solvs 0.0-1.3%. Instead of soda ash, tannin was used sometimes. The powd was gelatinized with eth-alc. Specific powds, such as $BN^3F$ & BN3F, are described under B(Poudre)
*Refs*: 1)Daniel(1902),75 2)Gody(1907),638 3)Marshall **1**(1917),295 4)Weaver(1917),134 5)Bebie(1943),126

**BNF Powder or Poudre BNF.** A new French Poudre B rifle powd(F=fusil=rifle). See under B(Poudre), item m
*Ref*: Marshall **1**(1917),296 & **3**(1932),85

**BN Propellants.** Liq BN monopropellants are described by T.D.Williams in Callery Chem Co Conf Bimonthly Rept No **3**(1960), Contract No a(s)58-454-d

**Boattail.** The tapered section at the rear(base) of a bullet or projectile. Its purpose is to streamline the shell body so that air friction effects are reduced and the stability in flight increased. A boattail design is effective in this respect at velocities less than 2900 ft/sec. When used in armor -piercing bullets, the boattail design reduces the no of cores(inside parts of bullets) broken during penetration, caused by the base striking against the plate while entering the target(See also under Bullets & Shells)
*Refs*: 1)Hayes(1938),559 & 661 2)M.M.Johnson & C.T.Haven, "Ammunition. Its History, Development and Use", Morrow,NY(1943) 3)Anon, "Ammunition Inspection Guide, "TM**9-1904** (1944),14 4)Ohart(1946),73-5 & 98

**Bobbinite.** Brit coal mining expl constg of BkPdr mixed with $CuSO_4$ & $(NH_4)_2SO_4$ or starch and paraffin wax. Two compns are reported: *Type 1* $KNO_3$ 62-65, charcoal 17-19, S 1.5-2.5, $(NH_4)_2SO_4$ 11 & $CuSO_4$ 1-6%; *Type 2* $KNO_3$ 63-66, charcoal 18.5-20, S 1.5-2.5, rice flour 7-9 & paraffin 2.5 -3.5%. These compns are nondetong expls with moisture content of 0-3.0% and d not exceeding 1.48 g/cc
*Refs*: 1)Marshall **1**(1917),89 2)Barnett(1919), 137-8 3)Pepin Lehalleur(1935),287 4)Thorpe **4**, (1940),553 5)CondChemDict(1942),288(not found

**Boboeuf Poudre.** An expl similar to Désignolle Powder(qv)
*Ref*: Daniel(1902),76

**Bodewig, Jacob**(1863-1934). Ger scientist who specialized in military expls
*Ref*: F.Lenze,SS **29**,191-2(1934) (short biography & obituary)

**Body of Projectile.** The cylindrical portion of a projectile directly behind the *bourrelet*(qv) and extending to the rotating band is commonly called the body. This portion is sl smaller in diam than the bourrelet and is usually 1-2 calibers in length
*Ref*: Anon, "Ammunition Inspection Guide", TM **9-1904**(1944), 11

**Bofors Detonating Cord or Bonocord.** It consists of a core of PETN contained within a woven tube of cotton threads protected by an outer covering of a plastic compn which is based on polyvinyl chloride or polyethene. Its outer diam is ca 5.5mm and the quantity of expl is ca 12g per meter. Bonocord is usually examined for appearance,resistance to cold, sensitivity to initiation, propagation of detonation and velocity of deton, as described in Ref
*Ref*: Anon,"Analytical Methods for Powders and Explosives", AB Bofors, Nobelkrut, Sweden(1960), 207-8

**Bofors Industries(Aktiebolaget Bofors)** of Sweden is one of the world's largest companies manufg expls, proplnts, ammo & weapons. It also manufs machinery and equipment for the construction of plants for the manuf of the above items(for instance, the plant for manufg TNT by the continuous method, recently installed at Azul in Argentina) and many other items, some of which will be mentioned below

The parent company, the so-called *AB Bofors*, is situated in the town of Karlskoga in the province of Värmland( about halfway betw Stockholm and Oslo)

The activities of Bofors Co date from 1646 when a royal charter was granted for the erection of two forge hammers in the mining district of Karlskoga. This smithy was gradually enlarged by the acquisition of other metallurgical plants located in the same district, and by the middle of the 19th century Bofors had developed into one of the largest iron works in Sweden. After its conversion in 1873 from private ownership to a limited company, Bofors gradually expanded to include a blast

furnace, an open-hearth furnace and a steel foundry the latter being the first of its kind in Sweden. In 1883, the Bofors Co began to manuf guns and ammo in newly erected workshops. As the items manufd by Bofors were of first quality, they soon established a reputation not only in Sweden but also in other countries. In 1894 the ownership of Bofors was acquired by Dr Alfred Nobel, the famous inventor of dynamite and other expls and founder of the Nobel prize. For large-scale experiments, Nobel built a lab at Björkborn, situated ca 2km from the Bofors plant. A large-scale manuf of expls & proplnts was begun shortly after the death of Nobel(1896) and the works became known as *AB Bofors Nobelkrut*(1898). The manuf of armor -plate and fuzes began in 1900. With equipment acquired prior to WWI, Bofors was able to manuf guns up to 250mm in size. The plant was considerably enlarged during WWI and an extensive proving ground was laid out. Since the end of the economic depression following WWI(ca 1920) the activities of Bofors have been continuously expanding. New workshops were erected(among them a subterranean one for the manuf of ammo) and new gun designs were developed(among which the well known 40mm Bofors Automatic Gun)

More recently, a new metallurgical plant, known as Kilstaverken, was erected near Bofors and extensive new labs were built for metallurgical and chemical research

In addn to expls, proplnts, ammo & weapons, the Bofors Industries now manuf many items for industrial use, such as chemicals, pharmaceuticals, high-alloy quality steels, castings and forgings. In 1958 it employed ca 8500 persons

Bofors Industries also own the following Swedish plants which are not located at Bofors or vicinity:
*AB Tidaholmsverken*, Tidaholm, founded in 1935 (manufg machinery for producing plastics & plastic products)
*Nydquist & Holm AB* (NOHAB), Trollhättan, acquired in 1936(manufg locomotives, railway cars, water turbines & Diesel engines)
*AB W.Dan Bergman*(Wedaverken), Södertälje, acquired in 1939(manufg Al & Mg alloy castings and light metal products)
*Ulvsunda Verkstäder AB*, Bromma-Stockholm, acquired in 1950(manufg grinding machine tools and hydraulic gears)

These four plants employed in 1958 ca 4500 persons, which makes a total of 13000 for the entire Bofors Industries

The following expls, proplnts, ammo, weapons and related items were manufd in 1958 by the AB Bofors: NG & NC proplnts, TNT, PETN, RDX, Hexotol(RDX/TNT), Hexotonal(RDX/TNT/Al), initiating expls, plastic expls, gaines, detonators, detonating fuses; *primers*- electric and non-electric; *shells*- HE, AP, star, smoke, mortar & incendiary; tracers, cartridge cases percussion tubes; *bombs*- HE, flare & photoflash; rocket-propelled depth charges; *rockets*- air-to-air, air-to-ground, flare & target; guided missiles; *guns*- 20 & 57mm aircraft, fully automatic; 40, 57 & 120mm field, anti-aircraft, fully automatic; 75mm to 210mm field guns, howitzers, self-propelled, semi-automatic, hand-layed; 40mm to 120mm naval anti-aircraft guns, fully-automatic, power-operated(deck & turret mountings); 120mm to 250mm naval turret guns, automatic, power-operated (single, twin & triple mountings); 75mm to 305mm coast-artillery, fully- and semi-automatic, power -operated(movable and fixed mountings, turret mountings); *launchers*-depth-charge & flare-rocket (fully automatic, power-operated deck guns with machine-driven hoists); *service & inspection equipment* such as Doppler radar, acceleration meters, condensator chronographs, gas-pressure meters, apparatus for servo-technical control of power-operated guns(such as transmitters, measuring devices, etc), devices for practice in handling matériel(such as loading training devices, practice & sub-caliber guns and demonstration apparatus for machine laying)
*Ref*: Aktiebolaget Bofors, Bofors, Sweden(1958) (an illustrated booklet, published by Bofors Industries)
*Note:* History of Bofors AB given in conf vol 3 of G.M.Chinn, "The Machine Gun", Govt Ptg Off, Washington,DC(1953) was not used as a source of information

**Bofors Plant Explosion**(Sweden). On Dec 17,1940 fire started in a wooden bldg used for shell loading and contg 3 melt kettles of TNT as well as a number of loaded shells. After 25 min of burning, the munition,but not the melt kettles contg TNT, exploded and scattered burning wood around the neighboring buildings. This started a series of new fires and explns which resulted in the destruction of 75 bldgs and a large amt of expls & munitions. The loss of life was comparatively small(11 killed) due to the fact that the explns were proceded by fire which gave sufficient time for most operators to escape
*Ref*: D.C.Westrell,SS **39**,85-7(1944)

**Bofors Plastic Explosive**(BPE) consists of PETN mixed with mineral oil by a special process. The

expl is yel in color, has a bulk d of ca 1.45 g/cm$^3$ and is mouldable at temps below minus 15°. Its stability is of the same order as cryst PETN

BPE is usually examined for appearance, composition, consistency and mouldability, matter insol in mixt acet & $CCl_4$, acidity, mp of PETN and explosion temp as described in Ref

*Ref*: Anon, "Analytical Methods for Powders and Explosives", AB Bofors Nobelkrut,Sweden(1960), 206-7

**Bofors Propellants.** A series of double-base propellants, known as *NK*(Nobelkrut), and manufd by the AB Bofors Nobelkrut of Sweden. The so-called *NK1* was the *ballistite*(qv) invented by A.Nobel in 1888 (Ref 1). More recently, *NK7*, a solventless propInt has been used since 1931 in the Swedish(and other countries) army & navy. According to Admiral Alvaro -Alberto(Ref 5), its compn is: NC(sol) 70-64, NG 24-29, "amilol"+vaseline 5-7 & DPhA 1%. The term "amilol" is applied to amyl phthalate, a high bp liq used as a gelatinizer, which was first introduced by Nobel.Lundholm(Ref 2) claimed the use of amyl phthalate as an anti-erosive agent in smokeless propInts. His compns contd: a)NC 60, NG 30 & diamyl phthalate 10% or b)NC 60, NG 30, diamyl phthalate 5 & mineral jelly 5%

Marqueyrol(Ref 3) analyzed some Bofors propInts and found that they contd NC(11.9%N) 72.1, NG 22.8 & diamyl phthalate 5.1%

*Refs*: 1)A.Nobel,BritP 1491(1888) 2)C.O.Lundholm,USP 701591(1901) & JSCI **21**,927(1902) 3)M.Marqueyrol,MP **23**,178,300(1928) & MP **24**,7 (1930) 4)Naoúm(1928),12 5)Alvaro-Alberto, Admiral of the Brazilian Navy,Rio de Janerio(1958); private communication(Oct 1958) 6)AB Bofors Nobelkrut,"Manual on Powders and Explosives", Bofors,Sweden(1960),169-90(Analytical procedures)

**Boghead Dynamite.** NG 60-62% absorbed on pulverized boghead 38-40%. Boghead is a carbonaceous rock or cannel with a high ash content, constg chiefly of Fe carbonate

*Refs*: 1)Daniel(1902),76 2)Hackh's(1944),136

**Boilers, Steam and Steam Power.** This subject is discussed in detail in Refs 1,2 & 3 and in other books on boilers

*Refs*: 1)L.A.Harding,"Steam Power Plant Engineering",Wiley,NY(1932) 2)J.H.Keenan & F.G. Keyes,"Thermodynamic Properties of Steam", Wiley,NY(1936) 3)T.E.Butterfield et al,"Steam and Gas Engineering",Van Nostrand,NY(1947)

**Boiling and Condensation Temperatures, Determination of .** Boiling is a state of ebullition or the rapid change from the liq to the vapor state. Condensation is the reverse process or the transformation of a substance from the gaseous to the liq state. The temp at which, under atmospheric or other specified press, a liq is transformed into a vapor(or temp at which the vapor press of liq equals that of the surrounding gas) is called the *boiling point*. The temp of the reverse phenomenon is called the *condensation point*.Apparatus & devices for detg boiling and condensation points of substances are described in the following Refs

*Refs*: 1)J.Barbaudy,"Contribution à l'Étude des Mélanges Liquides Ternaires", Hermann,Paris (1925) 2)C.Drucker in Ostwald-Luther,"Physiko -chemische Messungen",Leipzig(1931); Edwards Bros,Ann Arbor,Mich(1941) 2a)D.Quiggle et al, "Apparatus for Boiling Point Range Measurements", IEC,AnalEd **6**,466-8(1933) 3)V.Grignard,"Traité de Chimie Organique", Masson,Paris v1(1934) 4)A.Findlay, "Practical Physical Chemistry", Longmans-Green, London(1941) 5)W.G.Palmer, "Experimental Physical Chemistry", Cambridge-UnivPress, London (1941) 6)H.S.Taylor, "A Treatise on Physical Chemistry", Van Nostrand, NY(1942) 7)J.Reilly & W.N.Rae, "Physico-chemical Methods",vol 1(1943),pp 294-8 8)W. Swietoslawski,"Ebulliometric Measurements", Reinhold,NY(1945) 9)A.Weissberger,"Physical Methods in Organic Chemistry",Interscience,NY v 1(1945),pp 47-67 10)W.Swietoslawski,"Determination of Boiling and Condensation Temperatures", revised version by W.Swietoslawski & J.R.Anderson in 2nd Ed, v 1(1949),part 1,pp 107 -140 of Weissberger's "Physical Methods in Organic Chemistry", Interscience, NY

**Boiling Point vs Latent Heat of Vaporization.** This relationship for some secondary expls was investigated by Belyaev & Yuzefovich(Ref 1). The bp, ignition temp & latent heat of vaporization were detd for several expls:

| Explosive | Boiling Point, °C at: 2mm | 50mm | 760mm | Ignition Temp, °C | $Q_{vapzn}$ cal/mol |
|---|---|---|---|---|---|
| Methyl Nitrate | – | 5 | 66 | – | 4000 |
| Ethylene Dinitrate | 70 | 125 | 197 | 195-200 | 6500 |
| TNT | 190 | 245-50 | 300 | 295-300 | 10700 |
| PA | 195 | 255 | 325 | 300-310 | 6900 |
| TNB | 175 | 250 | 315 | – | 7600 |
| PETN | 160 | 180 | 200 | 215 | 17300 |
| NG | 125 | 180 | 245 | 200 | 7100 |

This table shows that the ignition temp approx coincides with the bp at 760mm Hg, which indicates that flammability is preceded by the formation of a large amt of vapor which ignites when heated. According to B & Y(Ref 1) TNT, PETN or PA neither detonates nor burns in vacuo, probably because the bp in vacuo is not near the ignition point. Their work was critically reviewed and questioned by Ahrens(Ref 2)

Since the bp of solid & liq expls often is the highest temp occuring in the condensed phase during combustion, it was attempted to det these constants by extrapolation from bp's detd at 15-20 & 80-100 mm Hg and by measuring the time $\tau$ of evapn of droplets weighing 0.02mg, placed on metal blocks kept at various temps T(abs). As a first approximation Belyaev(Ref 3) derived the formula:

$$\ln \tau = (\lambda/RT) + B, \text{ where}$$

$\lambda$ = heat of vapzn and B = constant. From the above equation Belyaev calcd the following approx values:

| Explosive | Boiling Point, °C | $Q_{vapzn}$ kcal/mol |
|---|---|---|
| Methyl Nitrate | 66 | 9 |
| Glycol Mononitrate | 200 | 14 |
| TNT | 335 | 17 |
| PA | 320 | 21 |
| PETN | 270 | 23 |
| RDX | 340 | 26 |
| TNB | 315 | 18 |
| MNT | 210 | 10 |
| DNT | 280 | 17 |
| Trinitrotrichlorobenzene | 270 | 13 |
| Trinitrocresol | 305 | 18 |
| TNAns | 310 | 15 |

Belyaev concluded that the *Trouton* const for these compds is abnormally high, contrary to a surmise by Ahrens

*Refs*: 1)A.F.Belyaev & N.A.Yuzefovich, DoklAkadN **27**,133-5(1940) (in English) & CA **34**,7607(1940) 2)H.Ahrens,SS **38**,159-63(1943) & CA **38**,2822(1944) 3)A.F.Belyaev,ZhFizKhim **22**,91-101(1948) & CA **42**,5227(1948)

**Bolivian Arms & Ammunition.** As far as is known Bolivia has no plants manufg expls, ammo or weapons. The only info we have concerns some rifles and carbines imported to Bolivia prior to WW II. Its 7.65mm Rifle, M1891 Mauser, was manufd in Germany; the 7.65mm Rifles M1924 & M1934/30, Mauser, were manufd in Belgium and the 11mm single-shot Rifle M1875 & Carbine M1879, Remington, were manufd in Spain(Refs 1 & 2). There is no info available concerning presently used expls, ammo or weapons

*Refs*: 1)W.H.B.Smith, "The NRA Book of Small Arms, v 2,Rifles", MilServPubgCo, Harrisburg,Pa, (1948),p 124 2)W.H.B.Smith, "The Book of Rifles", Stackpole Co, Harrisburg,Pa,2nd ed(1960),p 121

**Bollé, Erwin**(1885(?)-1938). Ger scientist who specialized in ballistics. He worked for 35 years at the Chemisch-Technische Reichsanstalt near Berlin and contributed numerous publications to the science of expls & ballistics

*Refs*: 1)Anon, SS **33**,334(1938) 2)W.Rimarski,SS **34**,226-7(1939)

**Bolometer.** A device for measuring minute quants of radiant heat by registering the change in conductivity of a black body(Ref 1). It is used in spectroscopy(Ref 2)

*Refs*: 1)Hackh's(1944),137 2)A.Weissberger, "Physical Methods of Organic Chemistry", Interscience,NY, v 1,part 2(1949),pp 1426-28(article by W.West)

**Bolovon O.** Austrian liq expl constg of 41ps m-dinitrobenzene & 49ps 100% $HNO_3$. Either Fe or Al can be used as container material for Bolovon O because the m-dinitrobenzene acts as an effective inhibitor for $HNO_3$

*Ref*: H.Horn& E.Fitzer,Berg u Hüttenmänn Monatsh-Montan Hochschule Leoben **98**,187-93(1935) & CA **48**,372-3(1954)

**Bolton,F.(Sir).** Proposed to chge cartridges made of cloth, with powd K nitrate(or other nitrate or chlorate) and to soak them, just before use, in liq nitrobenz or in a resin soln, molasses, etc. This compn and the process of mixing, in situ, are similar to that used in blasting expl *Rack-a-Rock* (qv)

*Ref*: Daniel(1902),76-7

**Bolton Powder.** A complex expl mixt, patented in 1868 in England, consisted of $NaNO_3$, sugar, K ferrocyanide, $K_2CO_3$, alum, charcoal, ash, lime, graphite & $CuCO_3$

*Ref*: Daniel(1902),76

**Boltzmann,L.**(1844-1906). Austrian physicist, who was professor at Graz, Munich & Vienna. Boltzmann's most important work was in mathematical physics. He made important contributions to the kinetic theory of gases and published papers on what is

now known as *Boltzmann's H-theorem* & on *Maxwell's* electromagnetic theory (See also Boltzmann's Constant and Boltzmann's Law)
*Ref*: EncyclBritannica,14th ed,v **3**(1929),p 829[Biography not listed in v **3**(1952)]

**Boltzmann's Constant.** A molecular constant in thermodynamic calculations of the energy of a single molecule or oscillator. It is expressed by $k = R/N$, where R is the *gas constant* per mol and N is the *Avogadro number*. Its value is $1.380 \times 10^{-16}$ erg per $^{o}C$
*Ref*: "The Van Nostrand Chemists's Dictionary", Van Nostrand,Princeton(1953),p 90

**Boltzmann's Law.** The law of the equipartition of energy to a molecular system. *Stefan-Boltzmann Law* states that the total energy radiated from a black body is proportional to its absolute temp raised to the fourth power. It is expressed by $E = \sigma (T^4 - T_0^4)$ where E = total energy in ergs, T = abs temp of the source, $T_0$ = abs temp of the surroundings, and $\sigma$ = Stefan-Boltzmann const, which is $1.36 \times 10^{-12}$ cal/sec/$cm^2$ of black body surface
*Ref*: The Van Nostrand Chemist's Dictionary, Van Nostrand,Princeton(1953),421,429 & 663

**Bomarc.** An Air Force surface-to-air interceptor -type homing missile, travelling at supersonic speeds. It has long range, uses a liq fuel plus two ramjet engines and has command radar guidance
*Refs*: 1)Glossary of Ord(1959),41 2)F.I.Ordway & R.C.Wakeford,"International Missile and Spacecraft Guide",McGraw-Hill,NY(1960),20(USA)

**Bomb.** See BOMBS

**Bomb, American(Initiating Device for).** Amer aerial bombs are initiated by nose and/or tail fuzes. There is also in some bombs, the *transverse* fuze which is fitted into a cavity of the body at right angles to its axis. The latter type of fuze, when used in depth bombs, is activated by pressure of water(hydrostatic, also called *thwartship* fuze)
*Ref*: A.B.Schilling, PicArsn,private communication (1961)

**Bombard** (from the Ital Bombo e ardore, meaning thunder & lighting). A medieval(14th century) piece of heavy ordnance used for throwing heavy, round stones and later for iron shot. The first bombards were made into circular bundles of longitudinal iron bars surrounded by rings or hoops which were driven over the bars while red hot and shrunk into place as they cooled. The bombards were usually short and sometimes had a large tapering bore with a powder chamber smaller than the bore. In appearance, if not in use, the bombards were the prototypes of the true mortars, which apparently were invented in Germany ca 1435(Ref 3). Accdg to Greener(Ref 1, p 18),some bombards were made of solid stone, being hollowed out until of sufficient depth to hold the chge of BkPdr; and it is probably that the term "mortar" originated from these weapons. Later types of bombards were made of wrought iron. A wrought-iron bombard which threw a stone weighing ca 160lb is shown on Plate I, inserted betw pp 469A & 469B of Ref 2
*Refs*: 1)W.W.Greener,"The Gun and Its Development", Cassell, Peter, Galpin & Co, London(1881) 2)EncyclBritannica **2**(1952), under Artillery 3)Collier's Encycl **2**(1957),295, under Artillery

**Bombard** (verb). To attack, formerly with bombards, now with any weapons hurling expl shells, bombs, grenades or rockets. Also to subject(a body) to the impingement of small particles or rays
*Ref*: Merriam-Webster's(1951),305

**Bombardelle.** A crude early firearm consisting of a tube on a long shaft
*Ref*: Merriam-Webster's(1951),305

**Bombardment.** A sustained attack upon a city, fortification or troops in position with bombs, shells, rockets or other missiles. The primary object of bombardment, preliminary to assault, is to destroy the defenses, to destroy or neutralize the weapons of the enemy and to demoralize the troops

Also, the action of bombarding atomic nuclei with rays or small particles
*Refs*: 1)EncyclBritannica **3**(1952),829 2)Glossary of Ord(1959), 41

**Bombardment Flares.** Pyrotechnic bombs designed to provide illumination for night bombardment. Several types of such flares are described by Ohart (1946),315-16. See also Bombs, Pyrotechnic, under BOMBS

**Bomb Blast.** The blast that results from the expln of a bomb
*Ref*: Glossary of Ord(1959),41

**Bomb, British(Initiating Devices for).** Brit initiating devices for bombs are divided into two groups:

*pistols* and *fuzes*. The term *pistol* is used to describe an initiating device which contains no expl components(primer, detonator or booster) as it is normally shipped or issued. It is purely a mech device, embodying certain arming and safety features for initiating expl components which are inserted in the bomb as a separate entity. These separate expl components used with the pistols are called *detonators*. Initiating devices which do contain expl components as integral parts, however, are termed *fuzes*. Generally, in addn to a primer -detonator combination, fuzes are also fitted with burster charges or boosters. As a general rule, pistols are used to initiate HE bombs, while Brit fuzes are employed in miscellaneous types of missiles, such as smoke bombs, flares, etc. In most bombs of 500-lb and under in wt, pistols are screwed directly into an *exploder* container which holds a *detonator* and booster pellets. In bombs weighing over 500 lb, the pistol is screwed into a detonator holder which, in turn, is threaded into the exploder container of the bomb. In this size of bomb, if a fuze is to be used, the detonator holder is omitted and the fuze is screwed directly into the exploder container

*Ref:* A.B.Schilling,PicArsn; private communication (1961)

**Bomb Calorimeter or Closed Bomb.** See under Calorimeter, Calorimetry and Calorimetric Tests

**Bombcannon of Krupp** (Die Krupp'sche 5.3-cm Bombenkanone, in Ger). A cannon which could shoot large bombs in a manner similar to rifle grenades. A detailed description is given in the Ref

*Ref:* Maj Berlin,SS **5**,285-88(1910)

**Bomb Carpet.** The fall of bombs, during so-called carpet bombing, in a creeping pattern to cover the area as with a carpet

*Ref:* Glossary of Ord(1959), 41 & 56

**Bomb Complete Round.** It consists of all the *components* necessary to drop and function the bomb. The usual components are: body with filler(constituting the payload), fin(or parachute) assembly (to stabilize the bomb in flight), fuze or fuzes(to function the bomb at the proper moment) and arming wire assembly. These components are usually assembled in the field just before the bomb is hoisted into the bomb bay of the aircraft, except in the case of small fragmentation bombs

*Refs:* 1)Ohart(1946),7 & 216 2)Glossary of Ord (1959),42

**Bomb Destruction.** See Bombs, Destruction of, in section which follows BOMBS

**Bomb Disposal.** See Bombs, Disposal of, in section which follows BOMBS

**Bomb Drop Test** (Bomb Functioning Test). See Vol 1,Physical Tests,p VIII

**Bomb for Determination of Heats of Combustion and Explosion.** See under Calorimetric Tests

**Bomb Functioning Test.** See Bomb Drop Test in Vol 1,p VIII

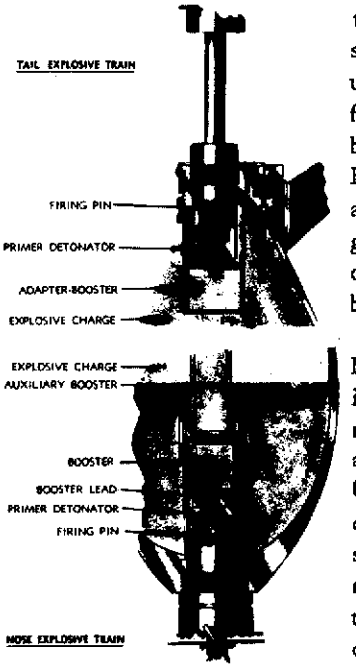
**Bomb Fuze.** See under Fuzes

**Bomb Handling.** See under Bombs, Packing, Storage, Handling, etc

**Bomb High Explosive Trains**(Used during WW II. The systems used in various HE bombs are briefly described in All&EnExpl(1946),pp 164-9(See also Fig)

**American** HE bombs of WWII were equipped in most cases with an impact fuze and the train consisted of the following components:

**A.** *Primer, Percussion Type:*




**Bomb Explosive Train**

a) Instantaneous Action- LA primer compn sensitized with LSt; used with a needle-type firing pin

b)Delay Action- MF/-$KClO_3/Sb_2S_3$(w or w/o abrasive such as ground glass or carborundum) compn; used with a blunt firing pin

**B.** *Delay Element:* BkPdr or, in dive bombing, $BaCrO_4$ was ignited by the flame from a percussion primer

**C.** *Relay*- A cup of LA covered with onion skin paper; it was ignited from the flame of the primer or of the delay chge and detonated with sufficient power to initiate the detonator

*Note:* Since the detonator was enclosed in a metallic(Al) case and was not in close contact with the delay, the relay was necessary to intensify the flame from the delay. In the case of instantaneous fuzes, the delay was by-passed and the relay was initiated directly from the primer

D. *Detonator.* It consisted of an upper or primary chge(LA sensitized by LSt) and a lower or base chge sometimes called the *sub-booster*(Tetryl). The relay detonated the upper chge and its action was intensified by the lower chge which, in turn, would detonate the booster(see below)

*Note*: For instantaneous fuzes, the primer and upper & lower detonators were enclosed in a container forming the so-called *primer-detonator*

E. *Booster.* It consisted of a large amt of Tetryl enclosed in a cylindrical container

F. *Burster or Main Charge.* It consisted of a fairly insensitive HE, such as TNT, Amatol, Expl D, Comp B, DBX, Torpex or Ednatol which could not be initiated positively by a detonator alone

**British** HE bomb train of WWII consisted of the following components:

A. *Primer.* It contained either LA or MF composition

B. *Delay.* It consisted of a BkPdr safety fuze

C. *Relay.* It contained BkPdr

D. *Detonator.* It contained either LA sensitized with LSt or 80/20-MF/$KClO_3$ compn

*Note:* All the above components were enclosed in a metallic tube and the ensemble was known as a *detonator.* For instantaneous action the delay and relay could be eliminated

E. *Exploder*(Booster). It consisted of compressed Tetryl or a combination of compressed Tetryl/TNT. The detonator tube was inserted in the exploder (See also Bombs, British, Initiating Devices)

F. *Bursting Charge.* It consisted of one of the following HE's: TNT, Amatol, Cyclotol, Pentolite, Minol II, Baratol, DBX, Amatex, Torpex, Shellite or Tritonal

**German** HE bomb train of WWII is described in PATR **2510**(1958),p Ger 20

**Italian** HE bomb train usually consisted of the following components:

A. *Primer-* MF composition

B. *Delay-* BkPdr

C. *Relay-* BkPdr

D. *Detonator-* LA sensitized with LSt

E. *Sub-booster*(also called *auxiliary booster*)- pressed RDX

F. *Booster*(also called *main booster*)- pressed TNT (See also under BOOSTER)

*Note*: All of the above components were held in cylindrical metal containers which were open at the top and at the bottom

G. *Bursting Charge-* Amatol, Ammonal, Cyclotol or TNT

**Japanese** HE bomb train usually consisted of the following components:

A. *Primer-* MF composition(Bakufun and Raibun) w/o abrasive; firing pin was generally the needle -type

B. *Delay-* BkPdr(Yuenyaku or Kokushokuyaku)

C. *Relay-* BkPdr

D. *Detonator-* LA(Chikkaen) in an open container

E. *Sub-booster-* generally Tetryl(Meiayaku)

F. *Booster-* pressed PA(Oshokuyaku) or RDX (Shouyaku) (in some smaller bombs)

*Note*: An *auxiliary booster* with pressed Type 98 Expl(70/30-TNAns/HNDPhA) was used in the tail of larger bombs

G. *Bursting Charge-* PA(pressed or cast), TNAns (Type 91 Expl), Type 98 Expl, Cyclotols(Nigotanoyaku-Mk2), 25/75-TNT/PA mixts(Chaoyaku), 75/25 -AN/RDX (Angayaku) and 50/50-Amatol(Shotoyaku)

**Bomb Inspection.** See under Bombs, Packing, Storage, etc.

**Bomb Loading.** See under Bombs, Packing, Storage, etc

**Bomb Maintenance.** See under Bombs, Packing, Storage, etc

**Bomb Manometric.** A manometric bomb is a device for measuring the pressure developed on expln and of some other props of expls and proplnts. One of the best known devices is the *Bichel Bomb*, briefly described in Vol 1, p VIII

Other devices include the Vieille Bomb, Manometric Crusher Bomb of the "Commission des Substances Explosives", Petavel Manometric Bomb, Manometric Piezoelectric Bomb, Krupp Bomb, etc

*Refs*: 1)Marshall **2**(1917),444-5 2)Marshall **3** (1932),133 3)Vennin,Burlot & Lécorché(1932), 72-87 4)Muraour(1947),83-90 5)A.Douillet & P.Miaud,MP **36**,277-84 (1954) (Studies of burning of BkPdr bags by means of manometric bomb) 6)G.Seitz,Explosivst **1955**,173-8 & 201-6(Investigation of the burning of proplnts in a Vieille bomb) 7)P.Miaud,MP **38**,181-8(1956) (Installation permitting ignition of a proplnt in the Vieille-type manometric bomb by means of a gaseous mixt and extinction of burning in the course of combn at a desired moment)

**Bomb Packing.** See under Bombs, Packing, Storage, etc

**Bomb, Plastic** (Bombe plastique in Fr, Plastik-Bombe in Ger), Accdg to description given in "Die Weltwoche", Zürich, 14 April 1961, abstracted by Dr Langhans in Explosivst **1962**,22, a "plastic bomb" usually consists of a plastic mass made into shape of a bomb or any other desired shape. Its compn varies from a Gelatindynamite to plastic expls based on TNT, PETN or RDX. Such a bomb can be easily detonated by a blasting cap, but it is practically insensitive to impact, friction or moderate heat. The plastic mass can easily be molded into any desired shape and can be attached to a target by sticking like chewing gum. Such a bomb can be easily transported or carried around hidden under clothing
*Note:* Plastic bomb was also described by A.Stettbacher in "Tages-Anzeiger für Stadt und Kanton, Zürich, 20 April, 1961

**Bombrini Parodi-Delfino Plants.** See Società Anonima Bombrini Parodi-Delfino under Italian War Plants

**Bomb Safety Precautions.** See under Bombs, Storage, etc

**Bomb Shipping.** See under Bombs, Packing, Storage, etc

**Bomb Storage and Surveillance.** See under Bombs, Packing, Storage, etc

**Bomb Tests.** The usual procedures for proving ground tests of bombs and related items may be classified as follows: hard surface test, functioning, fuze, arming wire, primer, detonator, adapter booster, burster, accuracy of bombing, bomb explosive, parachute units, chemical, pit, high & low panels and range bombing tests. The tests are described in the Ordnance Proof Manuals, Aberdeen Proving Ground, Maryland, Nos **9-11** (1949) and Nos **10-80** (1957)

**Bomb Transportation.** See under Bombs, Packing, Storage, etc

**Bomb, Unexploded** (UXB). A bomb which fails to expl on impact or immediately thereafter. It is considered to be a delayed action bomb until the contrary is proved
*Refs:* Glossary of Ord(1959),44 2)A.B.Hartley, "Unexploded Bomb, A History of Bomb Disposal", Norton & Co, NY(1959)

## BOMBS

(Bombe in Fr & in Ger, Bomba in Ital, Rus & Span)

A bomb is a hollow metallic, concrete, plastic or glass vessel of various shapes and sizes filled with either an explosive, a poisonous substance, an illuminant or smoke-producing compn. Bombs used before the invention of airplanes and submarines were mostly in the shape of spheres or cylinders and were either thrown by hand(such as a *hand grenade* or *anarchist's bomb*) or placed inside or underneath an object intended to be destroyed(such as a demolition bomb with a time mechanism). With the invention of dirigibles, airplanes and then helicopters, there appeared bombs which could be dropped from aboard them(aerial bombs); and with the invention of submarines there appeared bombs which could be dropped from aboard a ship or boat against a submarine(depth bomb). This bomb may also be dropped from aboard a plane, dirigible or helicopter. The most important of these are **aerial bombs**(bombs for aircraft)

*Historical.* Attempts to release bombs from the air were made after the balloon ("aerostate") (invented in 1783 by the Mongolfier in France) began to be used for military purposes. One of the first of such attempts was made in 1849 during the battle betw the Austrians & Venetians. When the wind was in the "proper" direction(blowing towards Venice) the Austrians attached small bombs, provided with time fuzes, to paper balloons kept aloft by means of heated air. When released, the balloons lifted the bombs to an altitude of ca 30 ft and drifted towards the city. When well within it, time fuzes exploded the bombs. Little damage resulted but the psychological effect was great. In the latter part of the 19th century several attempts were made to drop bombs with the help of crews, from observation balloons. This practice was discontinued in 1899 because it was forbidden by the Hague Convention [See also Balloons and Airships and Their Application in War]

In 1903, the Wright brothers constructed a successful airplane and in 1907 the Hague Convention's restriction against dropping bombs from the air was lifted. By 1910, military authorities of all the major powers began experimenting with planes, but at first the apparatus was regarded rather as a more efficient means for gaining info in the field than for dropping bombs. The earliest recorded use of bombs dropped from a plane was by the Italians ca 1911 during the war in Tripoli. These bombs were makeshift equipment, dropped

by hand over the side of a plane. The bombs had no fuzes because they were filled with NG, which exploded by itself on impact

Before WWI, the two countries who seem to have devoted the most time and money to aerial bombs were Germany & Spain. They developed bombs specially designed for use from aircraft. The Spaniards were the first to employ a bomb with mechanical fuze incorporating safety devices to protect airmen launching it. This was during the war in Morocco

During the first few weeks of WWI, planes were not equipped with guns or bombs, because planes were used only for observation purposes. The same might be said about dirigibles. At the end of the first 3 months, however, all the belligerents had organized squadrons to drop bombs. The first aerial bombs were dropped, by the Germans, Aug 30, 1914 on Paris. Only one plane was involved. One of the bombs penetrated a crowded subway sta, killing or mortally wounding ca 1000 persons. The other countries started to follow the German example. The Germans also used Zeppelins to some extent, especially in night raids on London. The first aerial bombs were modified shells(such as 3-in or 75-mm), equipped with fins and fuzes. As there were no sighting apparatus and no bomb racks, the aiming could not be accurate. Great improvements in construction of planes and of aerial bombs were made in the course of WWI and by the end of the war the aiming became very accurate. It became possible to bomb strategic objects without touching historical bldgs, especially churches, castles, palaces, etc. Special purpose bombs, such as demolition, fragmentation, chemical, incendiary, illuminating, propaganda, etc, made their appearance and the size of demolition bombs gradually was increased from 45-lb to 122-lb and then to 230-lb. The fragmentation bombs of WWI were the British 25-lb. Some other bombs were of French design but none of Amer design were used: the US Armed Forces used Fr & Brit bombs. Although quite a number of such bombs were manufd in the US in the latter part of WWI, none of them reached the front in time to be used. The most spectacular success of WWI was the bombing of the Turkish Army by Brit Gen Allenby

Considerable aerial bombing took place during the Spanish Civil War(1936-9), mostly by the Germans, who sided with Franco. The opposing Spanish faction was helped by the USSR, who supplied some armed airplanes and pilots. This war gave opportunity, especially to the Germans, to test the efficiency of newer bombs. The Ger electrical bomb fuze proved to be very successful and its further development and improvement were ordered in anticipation of WWII

The use of aerial bombing in WWI and the resulting damage, on both sides, were insignificant in comparison with what was done during WWII, when bombing became a most important weapon, especially for the US and GtBritain. Because of great improvements in aiming devices it became possible to achieve very precise bombing and to hit only targets of military importance. However this was not always done and many historical bldgs(such as in London,Münich,Nürnberg,Berlin,Heidelberg,etc) or even entire ancient cities(such as Caen, in Normandy or Dresden & Würzburg in Germany) were destroyed. Some of these places were still in ruins as recently as the summer of 1961 and those which were restored do not look exactly the same as before the war

Not only were aiming devices improved but more precise and deadly bombs were developed. The size of bombs was increased until wts of ca 20tons were reached. Some of the biggest bombs were known as *block busters*(qv) because the force of the blast of a single bomb could destroy an entire block or more(Refs 1,2,3,4 & 5). Another term used was *earthquake bombs*

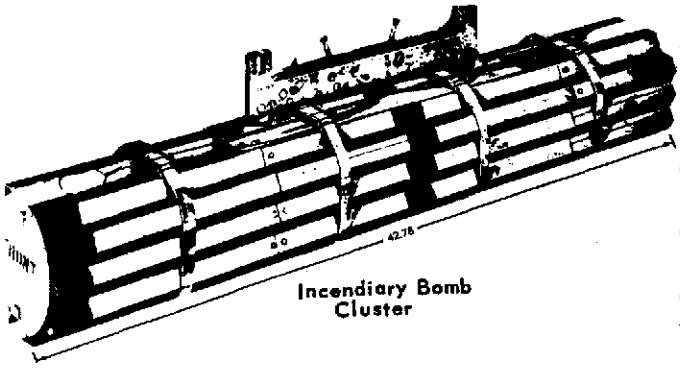
Toward the end of WWII, a so-called *atomic bomb* (see Vol 1,p A499-L) was developed in the US and used against two Japanese cities(Hiroshima & Nagasaki, Aug 1945), killing thousands of civilians and probably some soldiers. Many more civilians were injured and still more were invalided due to radiation. The use of these atomic bombs resulted in the end of the war with Japan and thereby saved the lives of numerous American personnel

A still more powerful and dangerous bomb*(hydrogen or thermonuclear bomb)* was developed in the US after WWII. The British,French & Russians now have the capability of manufg atomic & hydrogen bombs and eventually all nations may possess the secret

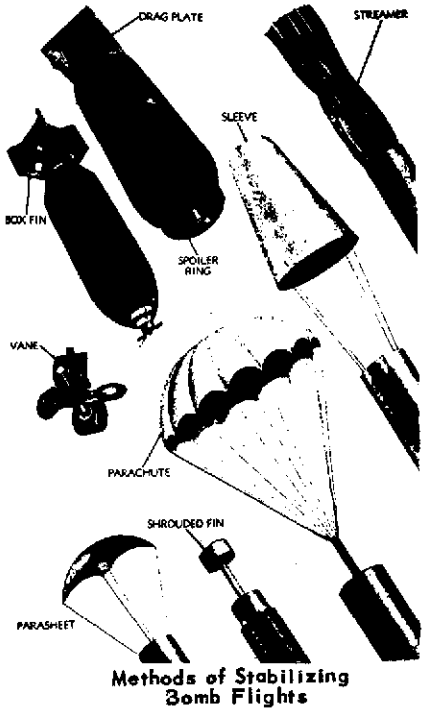
An ingenious method for "bombing" the USA with the aid of paper balloons was used by the Japanese during WWII.[See under Balloons and Airships and Their Application in War]

**Bombs for Aircraft(Aerial Bombs).** An aerial bomb is a type of ammo designed to be dropped from an aircraft in flight to inflict damage on the enemy or to serve a special purpose such as target identification or provision of a light source for photography A bomb consists usually of a metal container filled with expls or chemicals, a device for stabilizing

its flight so that it can be aimed accurately, a mechanism for explg the bomb at the target, and such safety devices as may be necessary to make the bomb safe to handle. The metal container, called the bomb body, is usually stream-lined with a rounded(ogival) nose and tapered tail. The stabilizing device is attached to the tail end of the body and generally consists of a sheet metal fin assembly, although a parachute unit, a sleeve or cloth streamers may be used. The mechanism for explg the chge is called a fuze and is generally placed in the nose or in the tail end of the body. Two or more fuzes (one in the nose and one in the tail) are occasionally used in the same bomb for different effects, for flexibility in use, or to insure reliability of functioning; that is, should one fuze malfunction, the other will cause the bomb to explode



Incendiary Bomb Cluster




Methods of Stabilizing Bomb Flights

Safety devices are usually built into the fuze and are held in place during storage and shipment by seal wires or cotter pins. When the bomb is prepd for use, the seal wire and/or cotter pins are replaced by an arming wire which is not removed until the bomb is dropped. Bombs are installed in airplanes by means of suspension lugs on the side of the body. Some bombs are carried in *racks*. Other bombs are assembled in *clusters* for dropping as a unit. (See Fig), Methods of stabilizing bomb flights are shown on Fig

According to TM 9-1900(Ref 15), the current US bombs may be classified: a) according to *filler-* as *explosive, chemical, incendiary, pyrotechnic & inert* and b) according to *use-* as *armor-piercing(AP) semi-armor-piercing(SAP), general purpose(GP), light case(LC), fragmentation(F), depth(D), gas, smoke* (or screening smokes), *incendiary(I), photoflash, target identification(TI), leaflet, practice, practice-target and dummy*

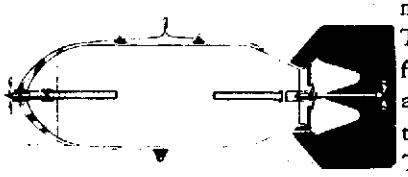
A slightly different designation was given for British bombs used during WWII, such as: **F**(fragmentation)(charged with amatol, TNT or cyclotol), **GP**(general purpose)(chged with Amatol or Cyclotol), **MC**(medium capacity) & **HC**(high capacity)(both types chged with Amatol, Amatex, TNT, Pentolite, Cyclotol, Torpex 2 or Minol 2), **DP**(deep penetration)(chged with Torpex), **SAP** (semi-armor-piercing)(chged with TNT), **AP** (armor-piercing)(chged with "shellite", see Vol 1,p Abbr 47), **AS**(antisubmarine)(chged with TNT, Cyclotol, Baratol or Torpex; some bombs with shaped charge effect), **DC**(aircraft depth charge) (chged with Amatol or Torpex), **B**(buoyancy)(chged with Torpex 2), **I**(incendiary), **LC**(light case chemical), **IT**(infantry training, **TI**(target identification), **AT**(antitank)(one of such bombs contained "Nobel's Explosive No 808" with shaped chge effect), **Smoke**(smoke) and **Practice**(practice). Most of these bombs corresponded in their use to US bombs. The so-called **DP** bomb was designed to give deep penetration of the earth and to produce heavy shock waves as a result of expln of its main chge. Their chge/wt ratio was ca 45%. The **B**(buoyancy) bomb was designed to be dropped in front of ships underway and to rise and detonate on contact with the ship's bottom. Its wt was ca 250lb

The designation of German WWII bombs is given in Refs 11 & 16, that of French and Italian bombs in Ref 13, of Japanese bombs in Refs 6 & 12 and of some Russian bombs in Ref 4a

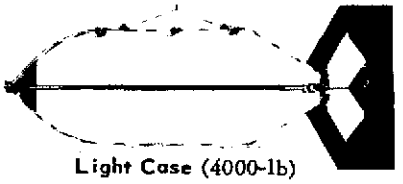
Following is a brief description of US types of bombs

**A) Bombs, Explosive or High Explosive(HE).** These are intended for the destruction of enemy bldgs, bridges, military installations and the like. The destructive effect is produced by deton(blast effect), by projection of the case(fragmentation), and by displacement of earth and structures(mining or heaving effect). They may be subdivided into: a) *General Purpose(GP)* (formerly called *demolition*).

These bombs are used for the majority of bombing operations and can produce blast, fragmentation or mining effects. They range in size from 100 to 1200lb and their chge (Tritonal, Comp B, TNT or Amatol) averages ca 50% of the total wt. The bomb body is cylindrical, has an ogival nose and tapers conically to the base. The bombs are generally fin-stabilized and nose and tail fuzes are used in most of them(Refs 7,9 & 15) (See Fig)


General Purpose (1000-lb)

b) *Light Case(LC)*. These and some demolition bombs are designed to carry a heavy chge of expl (70% or more of the total wt) to produce the max blast effect. They are similar in shape to GP bombs, but the case is lighter and thinner. They are equipped with proximity, instantaneous & non-delay fuzes to provide above ground bursts. Their total wt is usually betw 4000 & 10000 lb, but there are also heavier types. The so-called *blockbusters* (qv) are very heavy LC bombs(Refs 7,9 & 15)(See Fig)


Light Case (4000-lb)

*Note:* Brit designation LC means "light case chemical bombs"

c) *Armor-Piercing(AP)* and *Armor-Piercing Capped (APC)*. AP bombs are used to pierce highly-resistant targets, such as concrete bombproof construction and the heavy deck armor of battleships. The case is very thick at the nose and the wt of HE, sufficiently insensitive to withstand the force of impact(such as Expl D), is only ca 15% of the total wt. The bomb is provided with a delay-type tail fuze to permit deep penetration of the target before deton. The wt of these bombs is betw 1000 & 1600 lb(Refs 7,9 & 15) Some sizes also have a cap on the nose and they are designated APC(Ref 9,p 232)(See Figs)

Armor-Piercing (1000-lb)

Capped Armor-Piercing (1000-lb)

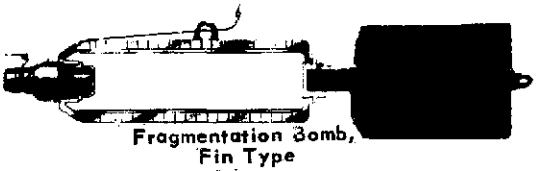
d) *Semi-Armor-Piercing(SAP)*. These are used against lightly armored ships and reinforced concrete construction. The case of SAP bombs is intermediate in thickness betw that of AP & GP bombs. The percentage of HE(usually Picratol) is ca 30% of the total wt. The bomb is provided with a delay type tail fuze. The total wt is from 500 to 2000 lb(Refs 7,9 & 15) (See Fig)

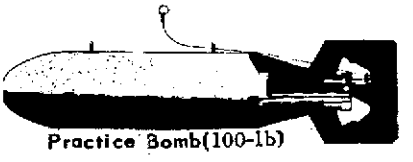
Semi-Armor-Piercing (1000-lb)

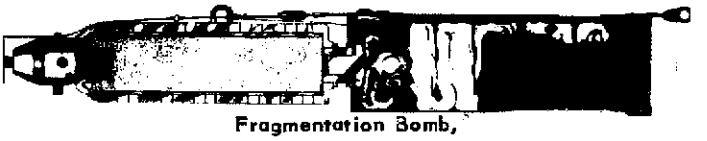
e) *Depth (D)* (called by Hayes *antisubmarine*). They are light-case bombs designed primarily for use against submarines. The case is cylindrical in shape and has a flat nose to reduce or prevent ricochet when dropped from planes flying at low altitudes. They are usually loaded with HBX, HBX-1 or TNT (70% of the total wt of the bomb) and provided with a hydrostatic tail fuze that functions at a predetermined depth. A nose fuze that functions with instantaneous action on impact may be used to produce a surface burst, when the bomb is used against a surface target(Refs 7,9 & 15)(See Fig)

Depth Bomb(650-lb)

f) *Fragmentation(F)*. They are designed for high-velocity projection of fragments from a square steel bar that is wound helically around the bomb, to inflict damage to personnel and light materiel. Their HE chge(usually Comp B or TNT) average only 14% of the total wt, which ranges from 4 to 260 lb. They are fin- or parachute-stabilized(See Figs), except the small(4-lb) bomb, which is stabilized with "butterfly wings" (See below under List of Bombs). All small and medium size bombs may be assembled in clusters and dropped from an airplane as a unit(Refs 7,9 & 15)


Fragmentation Bomb, Fin Type


Practice Bomb(100-lb)

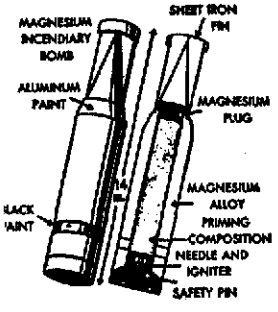

Fragmentation Bomb, Parachute Type

**B) Bombs, Chemical.** These may be subdivided into gas, smoke and incendiary

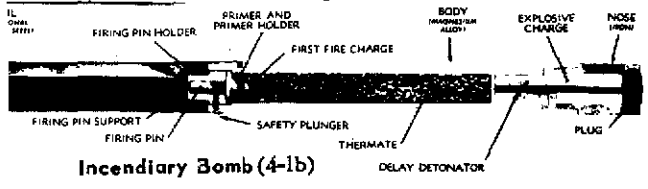
a) *Gas.* These bombs are filled with a chemical warfare agent(CWA) intended to produce on bursting of the bomb some physiological effects, including lung irritants, vesicants, lachrymators, irritant smokes and nerve and blood poisons(Refs 7,9 & 15) (See also Chemical Warfare Agents)

b) *Smoke.* These bombs are filled with a chemical [such as titanium tetrachloride(FM), hexachloroethane-zinc mixt(HC), chlorosulfonic acid-sulfur trioxide soln(FS), white phosphorus(WP) or plasticized white phosphoru s(PWP)] which produces on bursting of the bomb a dense smoke intended to screen the movements of troops, ships, location of artillery etc. Bombs filled with WP or PWP may be considered as a combination of screening smoke and incendiary because burning particles of WP are scattered together with the smoke(Refs 7,9 & 15) (See also under Chemical Warfare Agents)

c) *Incendiary(I).* Th ey are filled with material [such as thermite, thermate(TH), powd Mg, Al or their alloys, incendiary oil, napalm(NP), peptized NP (PTI), etc] which scatters and burns at extremely high temps; thus starting & intensifying fires and harassing & causing casualties. Some bombs have casings constructed of incendiary metals, such as Mg(Refs 7,9,15 & 16) (See Figs)



Incendiary Bomb (2-lb)



Incendiary Bomb (4-lb)

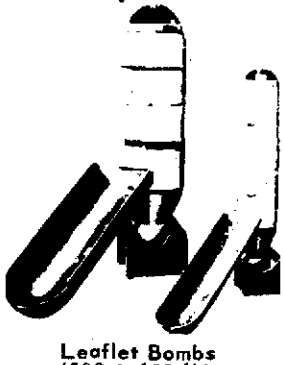
*Note:* All chemical bombs burst above the ground. They are provided with an instantaneous fuze and a *burster*(such as of Tetryl), which is used to rupture the bomb case and to release and assist in scattering the filler(Ref 2,p 604)

**C) Bombs, Pyrotechnic.** They contain pyrotechnic materials and are classified as bombs because of their similarity to bombs in body, fuzing and method of suspension. These bombs may be subdivided into:

a) *Photoflash.* These are thin-cased bombs designed to burst in the air and to produce a light of high intensity and short duration for night photography. The charge is either photographic flash powder(45% of total wt of the bomb) or metal-alloy dust(75% of total wt). The bombs are usually fin-stabilized and provided with mech time fuzes to produce air bursts(Refs 7,9 & 15)

b) *Target Identification (TI).* There are two kinds of TI bombs, both of which are fin-stabilized and provided with mech time nose fuzes to produce air burst. The *ground-marker* bomb contains pyrotechnic candles and is used to locate, illuminate and mark targets at night. The candles are ignited and ejected from the bomb tail and they continue to burn while falling to the ground. The *red-smoke* bomb is used to indicate a bomb release point when ground targets are not discernible. The bomb functions in air, the burster rupturing the case and expelling the filler(powdered hemitite, $Fe_2O_3$), which produces a persistent red cloud(Refs 7,9 & 15)

**D) Bombs, Leaflet.** They are 100 and 500-lb cylindrical bombs used to distribute literature from aircraft. The case is cut parallel to its axis into two equal parts which separate in the air when the fuze functions, thus allowing the leaflets to fall and disperse (Refs 7,9 & 15) (See Fig)


Leaflet Bombs (500 & 100-lb)

**E) Bombs, Practice and Practice Target.** Both kinds are used for practice to simulate service bombs. The *practice* bombs range from 23 to 250-lb but there are also miniature bombs in 3 and 4.5-lb fuzes. Most practice bombs have a *spotting charge*, others are completely inert. Some bombs are made of thin metal and they require sand-loading to give the desired wt before use, others do not require it because they are constructed completely of reinforced concrete except for the fin assembly and spotting chge. The *practice target* bombs are of 100-lb size and are used to produce a colored target on snow-covered ranges. These bombs are fitted with a nose fuze and a burster to scatter the hematite ($Fe_2O_3$) filler, producing a red coloration on the target area (Ref 15,pp 171-2)

**F) Bombs, Dummy.** Completely inert bombs and components used for training ground crews in assembling, fuzing, unfuzing and other handling details of bombs. Each type and wt of service bomb is represented by a corresponding dummy bomb. Dummy bombs are constructed from the

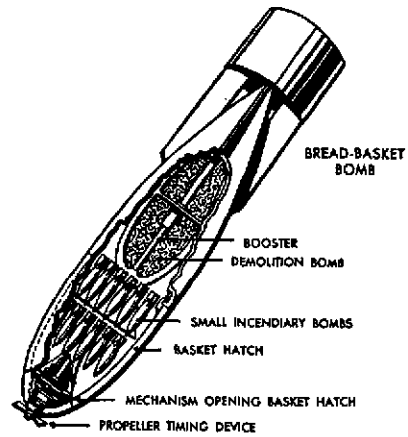
metal parts of service bombs, inert-loaded when necessary. Dummy bombs, unlike practice bombs, are not expendable, nor are they dropped for bombing practice(Ref 15,p 172)

Bombs may also be classified as listed in Ohart(Ref 7,p 221): a)according to **service use** as *service, practice & drill* b)according to **tactical use** as *GP, fragmentation, AP, SAP, chemical, light case & depth* c)according to the **actual filler** as *high-explosive, practice*(filled with a spotting chge), *chemical & miscellaneous* (filled with some special filler for a particular purpose) and d)according to **capacity** or the percentage of the filler wt to the total wt, as *low-capacity, medium-capacity* and *high-capacity*

Ohart further defines: a)*service* bombs as for use against the enemy to do damage to matériel and personnel, regardless of the filler b)*practice* bombs as for training of aircraft crews, especially bombadiers, the bombs have the same flight characteristics as service bombs but usually are loaded with a spotting charge to give indication of burst c)*drill* bombs as to train ground crews in assembling,fuzing, unfuzing and other handling of bombs; these are totally inert and are not expendable d) *low-capacity(LC)* bombs as less than 50% (percentage of filler wt to total wt), such as AP for which the capacity is 5-15%, SAP ca 30% and fragmentation ca 30% e)*medium-capacity(MC)* bombs as ca 50%, such as GP bombs and f)*high-capacity(HC)* bomb. The definition of the latter is given separately under Bomb, High Capacity (qv). Ohart also lists a *glide* bomb(Ref 7,p 202) and a *shaped-charge* bomb(Ref 7,p 240). The *glide* bomb is fitted with wings and other control equipment and released from a plane at high altitude. It then glides into the target at a fixed glide angle, say $10^{\circ}$, and is released at a safe distance from the target. If released at an altitude of 20000ft, the bomb would travel ca 20 miles before impact

Hayes(Ref 2,p 605) and TM 9-1980(Ref 9,p 55) classify the **inert** bombs as *practice, drill* and *gage*. The use of practice bombs is for the same purpose as the practice bomb described in TM 9-1900(Ref 15,p 171), while the use of the drill bomb is the same as that of the dummy bomb of Ref 15,p 172. The *gage* bomb serves for gaging and testing new types of airplanes for clearance, capacity and functioning of bomb racks. Such bombs are not issued to the field services

Newman(Ref 4,p 362) describes briefly the so-called *breadbasket* bomb made in two sections.




The center section was the demolition part filled with HE and equipped with a delayed-action fuze that acted only after the bomb penetrated the target. The nose section contained about a dozen small incendiary bombs which were released by a timing device at the desired moment. The incendiary bombs scattered burning material setting numerous intense fires, thus completing the destruction caused by HE

Some aerial bombs of WWII were equipped with rockets to give them added velocity and penetrating power after being launched from an aircraft

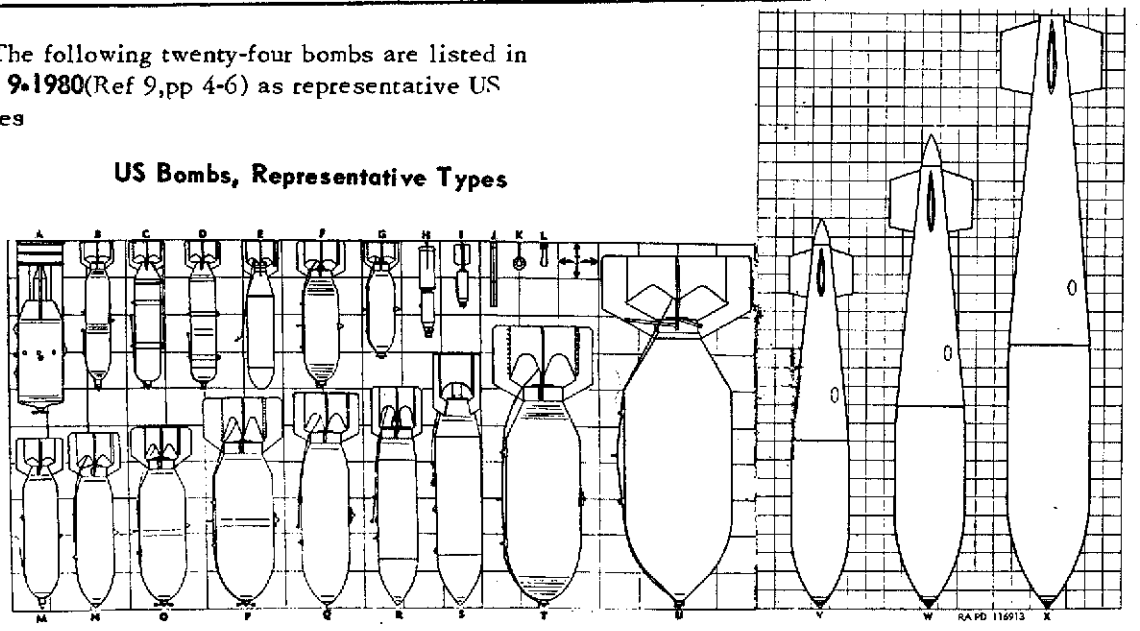
The foreign bombs of WWII are described in the following Department of the Army Manuals: TM **9-1985-1**(Conf)(Ref 10)-British; TM **9-1985-2**(Ref 11)-German; TM **9-1985-4**(Ref 12)-Japanese; TM **9-1985-6**(Ref 13)-French & Italian. The German bombs are also described in Ref 16, the Japanese in Ref 6 and some Russian bombs in Ref 3a

*Refs*: 1)Marshall **2**(1917),564 2)Hayes(1938), 598-616 3)Willy Ley,"Bombs and Bombing", Modern Age Books,NY(1941) 3a)G.Dyakov, Khimiya i Industriya **19**,285-93(1941)(Incendiary & HE bombs) 4)J.R.Newman,"The Tools of War", Doubleday,Doran & Co,NY(1943),270-90 & 357-63 4a)US Bomb Disposal School, "United States Bombs and Fuzes", Navy Yard,Washington,DC (1943) 5)Anon, "Ammunition Inspection Guide", War Dept Manual,TM **9-1904**(1944),548-708 6)Anon, "Handbook of Japanese Explosive Ordnance", OPNAV **30-3M**(1945),66-107 7)Ohart(1946)195-217 8)All&EnExpls(1946),164-9(Bomb high-explosive trains) 8a)J.M.King,"Bombs",Lecture delivered at PicArsn,Dover,NJ on 27February,1948 9)Anon, "Bombs for Aircraft",Dept of the Army Tech Manual TM **9-1980**(1950),1-59 10)Anon,"British Explosive Ordnance",Dept of the Army Tech Manual TM **9-1985-1**(1953)(Conf),1-158 & 178-204 11)Anon, "German Explosive Ordnance",TM **9-1985-2**(1953),

1 to 123 12)Anon,"Japanese Explosive Ordnance", TM **9-1985-4**(1953),1 to 121 13)Anon,"Italian and French Explosive Ordnance",TM **9-1985-6**(1953), 1 to 27 & 177 to 188 14)ArmamentEngrg(1954), 315-30(Aerial bombs) 14a)G.McAllister,Ed,"The Bomb:Challenge and Answer",Batsford,London (1955) 15)Anon,"Ammunition, General",Dept of the Army Tech Manual TM **9-1900**(1956),60-7 & 156 -72 15a)Federal Civil Defense Administration, "Radiation Physics and Bomb Phenomenology", USGPO,Washington,DC(1956) 16)PATR**2510**(1958), Ger 14 to Ger 20 17)Ordnance Ammunition Center, "Ammunition Complete Round Charts",Book III, Joliet,Ill(1959),Charts 1 to 10 incl 18)US Specifications for Bombs: MIL-B-13686(Bomb,body); MIL-B-14349(Bomb,4-lb,M114); MIL-B-20436 & MIL-B-20485(Bomb,fragmentation,4-lb,M83); MIL -B-20479(Bomb,fragmentation, 30-lb,M5, metal parts for); MIL-B-12097A(Bomb,gas,500-lb,AN-M78:components for); MIL-B-12029A(Bomb,gas,1000-lb,AN -M79; components for); MIL-B-13049A(Bomb,gas, 500-lb,AN-N78; CG loading assembly); MIL-B-13047A (Bomb,gas,1000-lb,AN-N79; AC or CG loading assembly); MIL-B-14322A(Bomb,gas,10-lb,M125A1); MIL-B-14440 & MIL-B-14322(Bomb,gas,persistent, GB,10-lb,M125A1); MIL-B-11932 & MIL-B-12654 (Bomb,gas,persistent,HD,115-lb,M70A1;components & loading assembly); MIL-B-12383 & MIL-B-12860A (Bomb,gas,persistent,HD,125-lb,M113; components & loading assembly); MIL-B-10514A(Bomb,incendiary 4-lb,AN-M50A3; components for); MIL-B-11392B (Bombs,incendiary,4-lb,AN-M50 types); MIL-B-10084 & MIL-B-11871A(Bomb,incendiary,PTI,10-lb,M74); MIL-B-13393 & MIL-B-13393A(Bomb,incendiary 100-lb,AN-M47A4); MIL-B-14152B((Bomb,500-lb, M115; components and metal parts assembly); MIL -B-12835(Bomb,leaflet,500-lb,M105A1,metal parts for); MIL-B-2529(Bomb ,light case,4000-lb,M56A2; metal parts assembly); MIL-B-1396(Bomb,photoflash AN-M46); MIL-B-11111 & MIL-B-11128(Bomb,photoflash,M120;metal parts for, loading, assembling & packing); MIL-B-12720 & MIL-B-14226(Bomb,photoflash,M122; metal parts for, loading, assembling & packing); MIL-B-11240 & MIL-B-11216(Bomb,photo-

The following twenty-four bombs are listed in TM **9-1980**(Ref 9,pp 4-6) as representative US types

**US Bombs, Representative Types**



A-BOMB, Depth, TNT, 350-lb, AN-Mk 54 Mod 1
B-BOMB, Gas, HD,115-lb,M70A1
C-BOMB, Photoflash,100-lb,AN-M46 (M46)
D-BOMB, Smoke, PWP,100-lb, AN-M47A4
E-BOMB, Practice,100-lb, M38A2
F-BOMB, GP, Tritonal,250-lb, AN-M57A1
G-BOMB, GP, TNT,100-lb AN-M30A1
H-BOMB, Fragmentation, TNT,23-lb, M72A1
I-BOMB, Fragmentation, TNT,20-lb, AN-M41A1
J-BOMB, Incendiary, 4-lb, AN-M50A2
K-BOMB, Fragmentation, TNT, 4-lb, M83
L-BOMB, Practice, Miniature, 3-lb, Mk23
M-Cluster, Fragmentation Bomb, M28A2(100-lb)
N-BOMB, SAP, Picratol,500-lb, AN-M58A2
O-BOMB, Incendiary,500-lb, AN-M76
P-BOMB, Gas,1000-lb, AN-M79
Q-BOMB, SAP, Picratol,1000-lb, AN-M59A1
R-BOMB, AP,Exp D,1000-lb,AN-Mk 33
S-BOMB, AP, Exp D,1600-lb,AN-Mk 1
T-BOMB, GP, Tritonal,2000-lb, AN-M66A2
U-BOMB, LC, TNT,4000-lb,M56A2(AN-M56A2)
V-BOMB, GP, Tritonal,12000-lb, M109 (T10)
W-BOMB, GP, Tritonal,22000-lb, M110 (T14)
X-BOMB, GP, Tritonal,44000-lb, T12

flash,T93;metal parts for, loading, assembling & packing); MIL-B-20498(Bomb,practice,17-lb,M37, low altitude,parachute type); MIL-B-20463(Bomb, practice,100-lb,M38A2; metal parts assembly); MIL-B-12880(Bomb,practice,250-lb,T52E3; metal parts for); MIL-B-20411 [Bomb,practice target,100 -lb,M75A1 and bomb,target identification,100-lb (smoke,red),M84A1; loading,assembling & packing)] MIL-B-10492A(Bomb,practice target,100-lb,M75A1, metal parts for); MIL-B-1397(Bomb,target identification,250-lbM89,M90,M91, M98 & M100); MIL-B-2521 (Bombs,seamless,metal parts assembly); MIL-B -20452(Bombs,fragmentation, 90-lb,M82; 120-lb,M86 and 220-lb,AN-M88; metal parts for); MIL-B-20497 (Bombs,fragmentation,M40A1,AN-M41A1,M72A1; and practice M71A1 & M73A1; parts for); MIL-B -10746B(Bombs,smoke or incendiary,AN-M47A4; 100-lb,PWP,WP,PTI,IM & NP;loading assembly); MIL-B-2501(Bombs,steel,GP & SAP,metal-arc welded; general spec for the construction of); MIL-B-2530 (Bombs,steel,GP &SAP,resistance welded; general spec for the construction of) 19)A.B.Schilling, PicArsn; private communication(1961)

**Additional References Discussing Principally Bomb Fillers**

A)A.Stettbacher,SS **12**,227-30(1917) (Incendiary & HE bombs) B)G.Dyakov,Khimiya i Industriya **19**, 285-93(1941) & CA **38**,2209(1944)(Russian HE & Incendiary bombs) C)W.Guldiman,Protar **7**,59-62 (1941) & CA **35**,5701(1941) (A brief description of airplane bombs, such as incendiary, HE, fragmentation, gas and special bombs) D)V.Leonard,BritP 537010(1941) & CA **36**,1496(1942) (Picryl fluoride as an expl chge for bombs) $D_1$)R.C.Allen,USP 2273166(1942) & CA **36**,3964(1942) (Explosive bomb contg a liquefied gas together with an explosive) E)L.Feiser et al,IEC **38**,768-73(1946) & CA **40**,5567(1946) (Napalm for use as a gelling or thickening agent employed in the gelled-gasoline fuels used as filling for incendiary bombs and in flame throwers) $E_1$)A.Grobstein,USP 2403656(1946) & CA **40**,5568(1946) (Nitrides of Li,Ce,K,Ca or La contained in a capsule may be placed in an incendiary bomb together with thermite or other mixt to produce high penetration and corrosive effect on burning) F)E.Wetter,Protar **12**,105-10 & 133-8 (1946);CA **40**,5920 & 6259(1946) (Comprehensive descriptive article on the history, development and types of airplane bombs and their fuzes) $F_1$)H. Graham,et al,CanChemProcessInds **30**,No 11,37-41 (1946) & CA **42**,4753(1948)[Bomb filling with 80/20 amatol(AN 80 & TNT 20%) is discussed] G)R.W. Hufford,ChemEngrg **53**,No 10,110-13(1946) & CA **41**,286(1947)(Chemical Warfare Service developments in incendiaries are described) H)H.K.Linzell,USP 2424937(1947) & CA **41**,7120(1947)(Incend mixt cont Al 51.1 & $CaSO_4$ 48.9% is recommended as filler for bombs because it develops more heat than thermite mixts) I)H.S.Beckman,Ordnance **32**,98-9 (1947)(HE bombs; method of manuf & loading) J)Anon,Ordnance **32**,364(1948)(21-Ton Bomb)(A bomb, 4.5' in diam, 26' 10" in length and weighing 42000 lb, was dropped at Muroc Air Base, Calif, from a Boeing B-29 Superfortress, for the purpose of testing. While lacking the destructive power of atomic missiles, the 21-ton bomb has an advantage in that it leaves no radioactivity which might deny use of a captured area to the attacking forces) K)C.M.Cawley et al,JInstPetroleum(London) **34**,90 -108(1948) & CA **42**,3961-2(1948)(Discussion on various incendiary mixts for bombs, mortar shells, etc) L)H.H.Cooke et al,USP 2445311(1948) & CA **42**,7985(1948)(Incorporation of isoölefin polymers of high mol wt with flammable naphtha produces a high-viscous mass almost semisolid in consistency which is suitable for incendiary bombs) $L_1$)D.P. O'Brien,USP 2451864(1948) & CA **43**,1190(1949) (An incendiary and demolition bomb contg Mg 2 oz, $Ca_3P_2$ 2 drams & $KClO_4$ 1 dram) M)H.H.Cooke et al, USP 2445312(1948) & CA **42**,7986(1948)(An incendiary bomb contg a nose fuze, a BkPdr ignition chge, a thermite nose chge and a tube of thermite extending through a gummy liq obtained by mixing naphtha with a high polymer, such as an isobutylene polymer, mol wt 50000 to 100000) N)K.J. Mysels,IEC **41**,1435-8(1949) & CA **43**,8179-80(1949) (Discussion on Napalm-mixt of Al disoaps used in incendiary bombs and flame throwers) $N_1$)J.M. King, "Bombs",Lecture delivered at Picatinny Arsenal,Feb,1948,27pp O)L.Finkelstein,USP 2553568)1951) & CA **45**,7354(1951)(Gelled gasoline incend compn is obtained by dissolving 3 ps of stearic acid in 88.75 ps of gasoline, adjusting the temp to 26° and stirring into a mixt of 5 ps isobutyl methacrylate, followed by 2 ps CaO and 1.25 ps of w. Careful addn of w gives control of the thickening rate) P)J.A.Southern et al, USP 2570990 (1951) & CA **46**,1768(1952)(A solidified fuel for incendiary bombs, grenades, flame throwers, etc consists of gasoline and 7-14% by wt of a soap -type gelling agent which is composed of Al oleate 50-75 & Al stearate 50-25 to which is added ca 1p of an oxyaromatic antioxidant compd and ca 4 -10 ps of Na oleate soap contg some Na stearate) Q)D.E.Floyd,USP 2662068(1954) & CA **48**,4222 (1954)(Polyamides, such as one prepd from 1 mol of cetylmalonic ester and 1 mol of 1,3-diaminopropane, are suitable gelling agents for gasoline,

octyl alc, cyclohexane, cyclohexanol, etc; the gels thus obtained are recommended for incendiary bombs and for flame throwers) R)M.D.Banus & J.J.McSharry,USP 2688575(1954) & CA **48**,14210(1954) (Prepn of fast-burning Ti or Zr powders for use in first-fire mixts for incendiary bombs or shells is described) S)L.Cohen,USP 2718462 & 2741629 (1956); CA **4916**271(1955) & **50**,11693(1956)(Al soaps of isoöctoic acid as gelling agents for liq hydrocarbons, the gels thus obtained are useful in incendiary bombs and in flame throwers) T)H.A. Richards et al,USP 2741177(1956) & CA **50**,10412 (1956)(The construction of an incendiary bomb for ejection of gelled on thickened fuels is described) U)R.E.Van Strien et al, USP 2751283, 2751284, 2751359, 2751360 & 2751361(1956); CA **50**,13483 (1956)(Al soap gelling agents for liq hydrocarbons used in incendiary bombs, grenades, & flame throwers are discussed) V)L.D.Jackson,USP 2796339(1957) & CA **51**,13399-13400(1957)(A mixt of Sr nitrate 60-90 & boron 40-10% produces a flame of great brilliancy & high temp and will burn under w; it is suitable for use in incendiary bombs or in flares) W)J.C.Loftin et al,USP 2824515(1958) & CA **52**,8560( 1958)(An incendiary bomb, which incorporates Cd in its casing or in the filler, produces a toxic CdO aerosol on burning) X)C.B. Linn,USP 2881060(1959) & CA **53**,14522(1959) (Some products obtained on condensation of hydrocarbons with carbohydrates are suitable as gelling agents for fiquids such as benzene, toluene, etc. The gels thus obtained are suitable as incendiary fuels for bombs) Y)R.E.Schaad,USP 2891852(1959) & CA **53**,17515(1959)(Materials suitable for filling bombs, grenades, etc are obtained by mixing nitrohydrocarbons, such as nitro- & dinitromethane, etc with devinylated ketoses or diaryl deoxyketitols, prepd by reaction of $C_{3-8}$ ketose sugars with $C_{6-24}$ aromatic hydrocarbons) Z)E.E.Bauer & G.Broughton, USP 2922703(1960) & CA **54**,7149-50(1960) [A thickened, stabilized incendiary fuel(having controlled consistency and which will not flake or scale) is prepd by adding to the hydrocarbon-soap mixt a silica gel which contains not over 5.5% w and passes at least a 28-mesh screen]

**Bombs, Destruction of.** Ths site used for the destruction of bombs, ammo or expls should be located at the max practicable distance available from all magazines, inhabited bldgs, public highways, railways and operating bldgs. The separation should not be less than 2400 ft unless pits or similar aids are used to limit the range of fragments. Sites must also be located in relation to the prevailing winds so that sparks will not be blown toward the location of expls, ammo, etc. Where possible, natural barricades should be utilized betw the site and operating bldgs and magazines. When destroying bombs, expls or ammo by burning, the possibility that the mass may detonate must be recognized and appropriate barriers or distance separation utilized for the protection of personnel and property

The area around the place of destruction must be cleared of dry brush, grass, leaves and other combustible materials for a radius of 200ft. The destruction grounds should be of well-packed earth which is free from large stones and deep cracks in which expl items might lodge. Expl materials shall not be burned or detonated on concrete mats

Fire-fighting facilities should be readily available to extinguish brush or grass fires and, if necessary, to wet down the ground betw burnings and at the close of each day's operation

Material awaiting destruction should be stored at not less than the min dist from adjacent temporary stores of expl materials and from bombs being destroyed, as required in Ref 2,Section 17 or in Ref 3,p 66-70. The material should be protected against accidental ignition or expln from fragments, grass fires, burning embers or detonating impulse originating in materials being destroyed. A bombproof shelter or a barricade of sufficient strength to provide protection for personnel should be erected at a dist of not less than 300ft from the destruction area

Bombs intended for destruction are usually transported in special trucks, marked "Explosives" and "Danger", with no more than two persons riding in the cab. As soon as all items have been removed, trucks should be withdrawn to a safe location until destruction is complete. No more than 100lb of bombs or other expl items are allowed to be destroyed at one time. The destruction of bombs larger than 100lb should not be undertaken in the US w/o approval of the Chief of Ordnance

Destruction of bombs may be done either by burning or by detonation

a)*Burning.* Bombs and their components(such as fuzes, adapter boosters & primer detonators) may be destroyed by burning. For this, the materials to be burned are placed in a pile and, after covering the pile with combustibles(such as wood, rags, paper, etc), some oil is poured over it. The ignition may be achieved either with a train of combustible material or with the aid of safety fuse of length sufficient to permit personnel to reach the protection of a shelter. The pile may also be ig-

nited with BkPdr squibs initiated by an electric current controlled from a safe distance. It may be necessary to tie in two or more squibs to assure ignition of the combustible train. Ignition of a stock-pile of bombs is often followed by detonation

In cases of misfires, the personnel shall not return to the place of destruction for at least 30 mins

When burning is completed, the ground must be thoroughly soaked with w if burning of the next batch is done within 24 hrs. If it is expected that toxic gases will be evolved on burning, personnel must wear gas masks or other protective devices

b)*Detonation*. Stock piles of bombs may be destroyed at the site by first removing the nose or tail plugs of bombs at(regular intervals in the pile)and inserting either chges of plastic expls or cut-down ½lb blocks of TNT in the empty fuze cavities. The chges should be primed for simultaneous deton and provisoin should be made for dual ignition by fitting at least two chges with blasting caps and sufficient length of safety fuse to permit all men to take safe cover

Explosive-contg bomb components may be detonated w/o being unpacked by placing ½ or 1-lb blocks of TNT in packing boxes in the amt of 1-lb blocks per each 100-lb(gross wt) of components. The chges of expls should be distributed throughout the pile and primed for simultaneous deton and dual ignition as described above for bombs. If chges are primed with a safety fuse, personnel should take cover after the fuse is ignited, and if electrical ignition is used, personnel should take cover before the circuit is closed

*Note*: When practicable, the stakes of bombs should be covered prior to detonation with earth in order to reduce the effective range of missiles and to assure high-order deton

*Refs*: 1)Anon,"Bombs for Aircraft",TM **9-1980** (1950),281-2 2)Anon,"Ordnance Safety Manual", ORDM **7-224**(1951),27-7 to 27-15 and Section 17 3)Anon,"Care, Handling, Preservation and Destruction of Ammunition",TM **9-1903**(1956),66-7 & 169-83 4)F.C.Iklé,"The Social Impact of Bomb Destruction", Univ of Oklahoma Press, Norman, Okla(1958)

**Bombs, Disposal of.** An unexploded enemy bomb represents great danger because the time of its expln is unknown, and if it explodes there could be real damage to life and property in residential areas, and interference with industrial production in factories and in other ways. It is, necessary, therefore, to dispose of any unexploded bombs as soon as possible. This is a very difficult and dangerous task because there exists a great variety of fuzes, many of which are equipped with anti-withdrawal devices. Only trained personnel must be used for bomb disposal. For this reason special Bomb Disposal Schools were established in various countries before and during WWII, most of which are still in existence. One of these schools is located at PicArsn,Dover,NJ

As it is impossible to give a brief instruction on bomb disposal, it is advisable to consult one of the special manuals, such as the British,"Bomb Disposal Manual"(listed in Ref 7) or US manuals and pamplets listed below as Refs 3,4,5 & 6

*Refs*: 1)R.L.Piech,"Bomb Disposal",Ordnance Sergeant,Bomb Disposal School, APG,Md(Aug 1943) pp 108-15(A brief discussion of bomb disposal during WWII) 2)US Bomb Disposal School,Potomac River Navy Yard,"United States Bombs and Fuzes", Washington,DC(1943) 3)Anon,"Shaped Charge Ammunition and Applications of Shaped Charges to Explosive Filled Ordnance",US Navy Dept,Bureau of Ordnance Publication OP **1720**(1947), 18-31 (Opening of explosive-filled bombs by firing small shaped charges into midsections of the bombs) 4)Anon,"Explosive Ordnance Reconnaissance and Disposal",Dept of the Army Field Manual, **9-40**(1953) 5)Anon, "Ordnance Service in the Field", FM **9-1**(1959) 6)Anon, "Ordnance Ammunition Service", FM **9-5**(1959) 7)A.B.Hartley, "Unexploded Bomb, A History of Bomb Disposal", Norton & Co,NY(1959)(A detailed description of bomb disposal conducted in GtBritian during and after WWII) 8)Office, Chief of Ordnance", Program for Neutralization and Disposal of Explosive Material", Technical Information Report G,TIR **G**, Washington,DC(1960(Conf)(Not used as a source of info)

**Bombs, Incendiary, Extinguishing of.** Bombs of the incendiary type were introduced during WWI but they were not effective and were comparatively easy to extinguish. In fact, some fires caused by explosive bombs striking near flammable materials were more difficult to extinguish because the destruction and débris which were wrought by the expln made it practically impossible for fire fighters to reach the seat of the fire. As explosive bombs are heavier, not as many can be carried by a plane as incendiary bombs

Incendiary bombs of WWI were of two types: a)*Thermite* that consisted of a steel shell filled

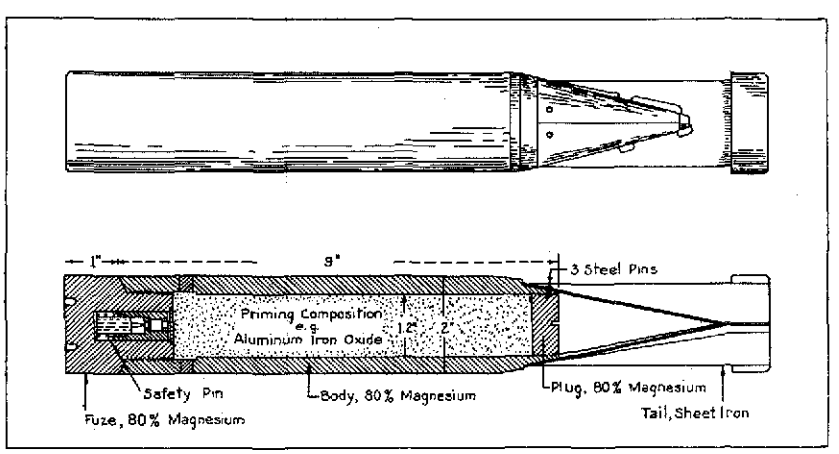
with a mixt of iron oxide and powdered Al. Upon ignition of this chge the following reaction takes place: $8Al + 3Fe_3O_4 \longrightarrow 4Al_2O_3 + 9Fe$, liberating a large amt of heat(temp 2500°C = 4532°F). As soon as the steel shell is penetrated by the heat, the reaction is nearly completed b)*Liquid fuel* bomb that consisted of a steel shell filled with 1 to 10kg of gasoline or other highly flammable liquid. Upon impact, this liquid was ignited, but with such small amts of incendiary liq the resulting fire would tend to burn out before penetrating and setting fire to the immediate surroundings. Only when the bomb struck very near some readily combustible material was there any danger(Ref 1)

The incendiary bombs of WWII were much more effective as also were the bombing planes. This made it possible to conduct incendiary bombing on a very large scale, especially by the Americans and British. For instance, accdg to Stettbacher (Ref 16), the number of incendiary bombs dropped on Köln(June 28,1943) was 100,000, on Berlin (March 8,1944) 200,000, Tokyo(March 15,1945) 325,000 and Hitler's Headquarters(May 25,1945) 600,000. Damages and casualties inflicted by incendiary bombs were about ten times greater than that caused by explosive bombs(Ref 16)

Many types of incendiary bombs were developed during WWII of which perhaps one of the most effective was the *"Elektron Bombe"* (electron bomb), invented by the Germans. It was made in sizes from 1 to 25kg. The most common, 1-kg bomb, is represented here. It consisted of a thick-walled Mg-Al alloy shell ca 9" in length and 2" in diam, weighing ca 0.8kg and was filled with a small amt of *thermite* mixt. Unlike the thermite-type incendiary bomb used during WWI, however, this thermite served only to ignite the Mg shell and not as the main incendiary material. The thermite reaction within the shell was initiated by an igniter in either the nose or tail of the shell. The igniter consisted of a small percussion cap into which a needle was driven when the bomb impacted. Unlike other types of bombs an electron bomb did not explode upon impact but started to burn on the inside. The violent reaction of thermite, developing a temp of ca 2500°(4532°F), caused jets of flame to be emitted from vent holes in the shell together with bits of molten Mg. These particles caught fire in the air and scattered in every direction for a distance of ca 50ft. The scattering continued as long as the thermite reaction proceded (ca 1 min). By this time the pressure in the bomb had decreased and the Mg shell became ignited. The shell then burned for 10-15 min at a temp of ca 1300°(2372°F) setting fire to any combustible material within a radius of several feet

Electron bombs were usually dropped from a height of a mile or more in lots of ten or twenty. A single plane could carry 1000-2000 of such bombs. An electron bomb dropped from a height of ca 1 mile would usually penetrate an ordinary wooden roof deck or covering material and start a fire in the top story or attic of a bldg. If not quickly extinguished the bomb would burn through the floors and set fires everywhere in the bldg

The electron bomb can be extinguished in any one of several ways, the idea being, of course, to extinguish it or bring it under control before it has caused a major fire. While the thermite reaction is in progress the bomb cannot be smothered be-




*Air Raid Precaution Handbook No 9, British Government*

**Drawing and cross-sectional view of a typical one-kilogram Electron bomb. Note blunt nose and awkward streamlining. With the exception of the sheet iron tail and firing mechanism, the bomb is constructed entirely of incendiary materials**

cause the oxygen entering the reaction comes from the iron oxide in the mixt and not from the atmosphere. When the thermite reaction has been completed, however, and the Mg-Al shell is burning, the bomb is dependent upon the atm for oxygen and can be smothered. Although water accelerates the burning of Mg(this acceleration can reduce the burning time from 10-15 mins to 2-3 mins) it can be used to combat the bomb if applied as described below

The reaction betw hot Mg and water is: $Mg + 2H_2O \rightarrow Mg(OH)_2 + H_2$ and between Al and water: $2Al + 3H_2O \rightarrow Al_2O_3 + 3H_2$. The hydrogen ignites and will burn without real damage so long as water is applied sparingly. However, if water is put on too fast, the hydrogen may accumulate faster than it can burn and will explode violently. To prevent the expln of hydrogen and to keep the bomb under control at the same time, a method using a jet surrounded by a spray of water was found by the British authorities to be most satisfactory. To fight fire by this method at least two persons and special equipment are required. The equipment consists of a bucket, a double-action hand pump, 30ft of hose and a special one-eighth-inch nozzle. The 1st man pumps 80 strokes a min to keep a pressure strong enough to throw a jet 30 ft and a spray 15 ft wide. The 2nd man, in a prone position(protecting himself from bits of burning Mg), holds the nozzle and directs the jet into the seat of the fire and not indiscriminately into the smoke and flame. The spray serves to wet down the area surrounding the bomb and thus prevents the spreading of fire. The delivery from the system should not be more than 1 3/4 gallons a minute. Water should never be poured onto an electron bomb from a pail or bucket(Ref 1,p 116; Ref 4,p 7; Ref 6,p 7; Ref 7,p 37; Ref 11,p 5 & Ref 13,p 7)

Electron bomb fires can also be brought under control by using dry sand or other granular materials, such as slag, pumice, ash, kaolin, finely divided iron, graphite, etc. In this country, we have been using special coml powders, such as *GI* & others. Their compositions are unknown to us. The granular material should be dumped over the bomb (completely covering it) from a long-handled scoop shovel and when the heat and glare of the bomb have subsided sufficiently, the bomb should be scooped up, together with its covering, with the same shovel and placed in a metallic container partly filled with sand for transporting it from the bldg. Once the bomb has been removed, any resulting fires can be extinguished by ordinary methods(Ref 1,pp 117-18; Ref 7,p 38; Ref 12,p 5 & Ref 13,p 7)

Of the various types of fire extinguishers only those of the water-solution type would be effective against the electron bomb, and usually more than one extinguisher would be required. The soln should be played upon the bomb in the same way as water from a nozzle. A *foam extinguisher* might also be used but under no circumstances should a *carbon tetrachloride extinguisher* be used. It is not only ineffective but it may cause dangerous gas to be generated(Ref 1,p 118; Ref 6,p 39; Ref 13,p 7 & Ref 15)

Still another device used to extinguish a small incendiary bomb was a *snuffer*. It consisted of a large cup(dome) about 1½ft in diam, made of a wire mesh sprayed inside and outside with asbestos fiber. The cup was attached in an inverted position to the end of a long rod and when placed over the burning bomb, smothered it(Ref 1,p 118 & Ref 4, p 6)

In Ref 11,p 5, a Russian method for extinguishing small electron and some other bombs is described. It consisted of "dunking" the burning bomb in a large container(such as a barrel) full of cold water. It was claimed that this method is very effective because here the Mg-Al alloy is chilled below its mp so suddenly that it stops burning almost immediately. There should be, however, sufficient water to completely immerse the bomb, otherwise the burning will proceed even more vigorously than without water(Ref 11,p 5)

The methods described above are applicable only in case of small(1-2-kg) bombs, the heavier type bombs require experienced firemen for extinguishing fires(Ref 1,p 120)

Another type of bomb used to a considerable extent during WWII was the *multiple effect bomb*. It contained either magnesium or phosphorus in separate units. These units were ejected from the bomb upon impact and ignition and scattered over a wide area. The burning Mg units could be handled in the same manner as the electron bomb. The P units could be treated with water, but should be removed to a safe place before allowing them to dry(Ref 1,p 120)

A new type of bomb was developed by the Germans in 1942. It was an incendiary bomb which contained a fairly large chge of explosive. When it landed, the bomb burned for several minutes(up to 7 mins) and then suddenly exploded, scattering the fragments in a manner similar to antipersonnel bombs. The idea was to keep fire fighters at a respectable distance while the fire gained headway before expln. The bomb could not be extinguished

by any of the methods requiring approach to the bomb, such as sand, powders of "snuffer" methods. The method recommended by the NFPA to fight a burning bomb before it explodes is to throw a strong jet of water from a safe distance while standing behind some suitable cover, such as a wall or barricade. Lath and plaster walls, wooden doors, tables or chairs do not offer full protection from an expln. If a good cover is not available, personal risk can be greatly reduced by assuming a crouching or prone position. Care should be exercised to expose no more than one hand while playing a stream of water on the area surrounding unexploded bombs(Ref 14,p 7)

In the pamphlet "Fire Fighting for Householders", PA-B-4, issued by the Office of Civil and Defense Mobilization, USGovtPtgOff, Washington,DC(1958), several methods for fighting fires caused by various bombs, including A- and H-bombs, are briefly described

*Refs:* 1)J.A.West,Jr,"Total Fire-The Incendiary Bomb", Quarterly of the National Fire Protection Association(NFPA),Boston,Mass(Oct 1940),102-24 2)H.S.Hirst & A.B.Guise,"Magnesium and Its Alloys", Ibid(Oct 1940),125-35 3)A.B.Guise,"Chemical Extinguishers for Incendiary Bombs",Ibid(Oct 1940), 137-8 4)Anon,"Incendiary Bombs. What the British Fire Fighters Learned About Them",Volunteer Firemen,NFPA,Boston,Mass(Nov 1940),6-9 5)W.J. Scott,"Handling Explosives and Incendiary Bomb Fires",Ibid(Feb 1941),6-7 6)A.B.Guise,"Incendiary Bomb Fires",Ibid(Sept 1941),6-7 7)Anon, "A Handbook for Air Raid Wardens",US Office of Civilian Defense,USGovtPtgOff,Washington,DC (1941),36-9 8)G.Durston et al, USP 2232695 (1941) & CA **35**,3818(1941)(A mixt of powdered fusible solid org subst, such as bitumen, with a inorg subst such as slate powd for extinguishing ignited incendiary bombs) 9)P.A.Barreau,BritP 533470(1941) & CA **36**,1182(1942) (A powd dealing with incendiary bombs consists of borax, carbonate or bicarbonate of an alk earth metal, fire clay & alum) 10)W.O.Petzold,BritP 545514(1942) & CA **37**,1606(1943)(Sawdust impregnated with chlorides of Ca, Zn & $NH_4$, to which a little Na borate is added, can be used to combat incendiary bombs, oil bombs or other fires) 11)Anon,"Fire From the Air, Volunteer Firemen,NFPA,Boston,Mass(July 1942),4-5 12)Anon,"Chicago Fire Department Teaches Simple Way to Fight Fire Bombs",Ibid (August 1942),5 13)Anon,"Cincinnati Teaches Citizens to Control Fires from Bombs",Ibid(Sept 1942),7 14)Anon,"Beware of Explosive Incendiaries. New German Fire Bombs Pack a Deadly Explosive Charge to Keep Fire Crews out of Range Until Fire Has Spread",Ibid(Dec 1942),6-7 15)S.J. Pearce et al,USBurMinesReptInvestigations **RI 3686**(1943) & CA **37**,2578-9(1943)(Application of carbon-tetrachloride-type fire extinguisher should not be used to extinguish burning Mg or thermite -Mg incendiary bombs, but its use on other fires should not be discouraged) 15a)H.Bond,Edit,"Fire and the Air War", NFPA,Boston,Mass(1946) 16)Stettbacher(1948),129 17)PATR **2510**(1958)p Ger 17 & 19(German incendiary bombs) 17a)R.T. McCutchan,USP 2888072(1959) & CA **53**,10765 (1959) (Soln of $H_3BO_3$ in glycols for extinguishing burning Mg,etc) 17b)Anon,C&EN **39**, 63(Oct 23, 1961) (Multipurpose extinguishing agent of Ansul ChemCo, Marinette,Wis) 18)Chester I.Babcock, National Fire Protection Association,60 Batterymarch St,Boston 10,Mass; private communication

**Bombs, Packing, Storage, Handling, Safety Precautions, Maintenance, Inspection, Surveillance, Shipping and Transportation of.**

All bombs, except the very largest, are *packed* in wooden boxes or crates. The fin assemblies for the larger bombs are also crated when packed separately from the bombs. Some bombs are packed with fuzes inserted but with primer-detonators removed. However, the fuzes are usually removed and packed in sealed moisture-proof containers. In the latter case the fuze wells in the bombs must be closed with plugs. Some fuzes are packed in the same containers with the bombs, others separately. Bombs and components are stored as shipped. Complete rounds should not be assembled in advance of requirements and assembled rounds should be carried with sealing wires and safety in place at all times until installation in the plane. The arming wire should remain in place until the bomb is released, or until the safety pins and sealing wire are replaced and secured

Bombs and components should be *stored* in an area set aside for this purpose. Such an area should be located at greater than missile distance from artillery ammo storage and removed from operating areas, inhabited areas and public highways & railways. These distances are given in Quantity -Distance Table for classes 9 & 10, in Ref 5,pp 66 -7 and in Sect 7, Ref 7. The magazines must be fireproof

In *storing* bombs, the following conditions must be fulfilled:

a)It is preferable to store only one type of bomb in a magazine or igloo at one time. However, when conditions do not permit individual storing of bombs

by type, bombs filled with Amatol, Expl D, Picratol or TNT may be stored together. Tritonal, Torpex and HBX-loaded bombs may also be stored together b)GP, AP, SAP, LC, or depth bombs should not be stored with any other type of ammo or expls c)Photoflash bombs should not be stored with any other type of ammo, but when the total amt of expls is less than 1000 lbs, the bombs may be stored with small arms ammo d)Fuzes or primer-detonators should be stored in a separate magazine e)Bombs should be stored on steel or iron dunnage. For storage in other than igloo or corbetta-type magazines, steel dunnage should be electrically connected and grounded

Extreme *safety* precautions must be exercized in *handling* bombs(especially GP & LC bombs) and protecting them from shock or heat. Containers should not be tumbled, dragged, thrown, dropped on each other or rolled on the floor. Bombs equipped with shipping bands may be rolled if care is exercized

*Maintenance* of bombs(maintaining them in servicable condition for immediate use) includes derusting, repainting and removal of exudate from the bombs and the floor of magazines. Removal of exudate from the floor is done by pouring hot water over it and scrubbing. When a comparatively small amt of exudate is present on the exterior of bombs, it can be removed with acetone and the bombs considered suitable for issue. Where excessibe exudate is present on the exterior of bombs, the lots involved should be reported to the Ordnance Ammunition Command, Joliet, Ill and held for disposition

Each lot of bombs in storage must be *inspected* each year for rust, corrosion, exudation and other signs of deterioration, paying particular attention to the condition of fuze wells and threads. If any oily stains are observed on the surface of a bomb container, it must be immediately opened and the bomb examined for exudation. Bombs with a large amt of exudation must be destroyed, as briefly described under Bombs, Destruction of. In addn to the inspection mentioned above, several representative samples should be selected from each lot and sent to the ballistic lab for testing. All of these operns may be called *surveillance*

Bombs are *shipped* in the same containers as used in storage. Each container must be inspected and any with oily specks must be removed and the bombs examined for exudation. *Transportation* of bombs within the USA is goverend by "Regulations for the Transportation of Explosives and Other Dangerous Articles by Freight", established by ICC(Interstate Commerce Commission)(Freight Tariff No 8). These regulations are given in Sect 11,Ref 7

*Refs*: 1)Anon,"Safety and Storage Manual for Explosives and Ammunition",OO Form No**5994**,US Army Chief of Ordnance,Washington,DC(1928), Sect XI 2)Anon,"Ammunition Inspection Guide", TM **9-1904**(1944),552-708 3)Anon,"Bombs for Aircraft", TM **9-1910**(1950),55-59 4)Anon,"Ordnance Safety Manual",ORDM **7-224**(1951),20-7 5)Anon,"Care, Handling, Preservation and Destruction of Ammunition",TM **9-1903**(1956),66-7, 86-7 & 147 6)Anon,"Ammunition General",TM **9-1900**(1956),160 & 183 7)Sax(1957),Sections 7 & 11

### List of Bombs

**Bombs, Aerial or Aircraft.** See under BOMBS

**Bombs, Aircraft Depth Charge(DC).** Designation of a British bomb used during WWII

**Bombs, AN-M-69.** See Vol 1,p A457-R

**Bombs, Antipersonnel.** A small fragmentation bomb designed for use against personnel. See fragmentation Bomb, under Bombs

**Bombs, Antisubmarine(AS).** Designation of a British bomb used during WWII

**Bombs, Antitank(AT).** These were Brit bombs(there being no special US bombs) designed to be used against tanks or other armored vehicles. Probably general purpose (GP) bombs were more suitable as A/T than other types

*Refs*: A.B.Shilling,PicArsn; private communication (1961)

**Bombs, Atomic.** See Atomic(or Nuclear) Bomb in Vol 1,p A499-L. Explosion of atomic bomb in the earth atmosphere was discussed by H.Schwentek, Explosivst **1961**,49-55

**Bombs, Blast.** See LC(light case) bomb briefly described under BOMBS

**Bombs, Blockbuster.** See Blockbusters; also under BOMBS

**Bombs, Buoyancy(B)** (Brit). See under BOMBS

**Bombs, Breadbasket.** See under BOMBS

**Bombs, British.** Bombs used during WWII are briefly described in conf "British Explosive Ordnance", TM **9-1985-1**(1953), 1-158 & 178-204

**Bombs, Butterfly.** Small fragmentation or anti-personnel bombs equipped with two folding wings which rotate and arm the fuze as the bomb descends. Designed to be dropped in clusters, the bombs are frequently fitted with anti-disturbance or delay fuzes (See Fig)
*Refs*: 1)Anon, "Ammunition General", TM **9-1900**(1956), 168
2)Glossary of Ordnance(1959) 41

**Bomb, Butterfly, 4-lbs**

**Bombs, "Buzz".** Brit colloquial term for the Ger WWII flying bomb **V-1**(Vergeltungswaffe Eins) (Revenge Weapon 1) so named for the buzz-like noise of its pulse-jet engine(Ref 1). Officially the bomb was known in Germany as *FZG-76* and in the US it was designated as *JB-2 Bomb*. For its description see Refs 2 & 3
*Refs*: 1)F.Bellinger et al,IEC **38**,161-9(1946) 2)F.Ross,Jr,"Guided Missiles, Rockets and Torpedoes", Lothrop, Lee & Shepard,NY(1951),14-20 3)PATR **2510**(1958),pp Ger 213-15

**Bombs Carrying Paper Balloons**(Japanese). See under Balloons and Airships and Their Application in War

**Bombs, Chemical.** See under BOMBS. The Brit desgn LC means "light case chemical bomb"

**Bombs, Chemical Agent.** Bombs contg a chemical agent as a main chge. See Bombs, Chemical under BOMBS.

**Bombs, Cobalt.** Atomic or hydrogen bombs encased in cobalt which, upon detonation, would be transformed into deadly radioactive dust. These bombs, at present, are of theoretical interest inasmuch as they are considered too dangerous to use since the dust would effect friend, foe and neutral alike. In the detonation process, part of the $Co^{59}$ is converted to $Co^{60}$, a very radioactive substance
*Ref*: Glossary of Ord(1959),41

**Bombs, Conventional.** Any nonatomic bomb designed primarily for its expl effect, as distinguished from a chem, incendiary, leaflet or any other special purpose bomb
*Ref*: Glossary of Ord(1959),42

**Bombs, Delayed Action.** Bombs having a delay fuze which may vary from a fraction of a second to several days after impact. Bombs having short delay fuzes are used to penetrate targets before exploding; bombs having medium delay fuzes are used in low-altitude bombing to allow the plane to move away from the point of impact before deton; bombs having long delay fuzes are used either to deny territory to the enemy for a period of time or to allow successive waves of planes to drop their bombs before any of them detonate

A bomb which may be set to expl some time after being dropped or planted is known as a *time bomb*. Short-delay fuzed aerial bombs are usually not classified as time bombs
*Ref*: Glossary of Ord(1959),42 & 44

**Bombs, Deep Penetration**(DP) (Brit). See under BOMBS

**Bombs, Demolition.** Former classification for bombs that exploded after short penetration, accomplishing damage and destruction by both blast and underground explosion. A demolition bomb of WWII had a charge approx equal to 50% of the bomb's total wt. The present classification of such a bomb is GP(general purpose). See also under BOMBS
*Ref*: Glossary of Ord(1959),42

**Bombs, Depth(D).** See under BOMBS

**Bombs, Drill.** See under BOMBS

**Bombs, Dynamite.** Makeshift bombs obtained by tying several sticks of dynamite into a bundle
*Ref*: Glossary of Ord(1959),42

**Bombs, Earthquake.** Large bombs which, when dropped, penetrate and explode beneath the surface of the earth(as deep as 20ft) producing an effect similar to an earthquake(Refs 1 & 3)

According to Ohart(Ref 2), such bombs do more damage after some penetration than they do if detonated in the open except possible for the very large HC(high-capacity) *blockbusters*(qv), of 4000 -lb and larger which cover a greater area(in their open-air blast effect) than a normal size bldg
*Refs*: 1)J.R.Newman,"Tools of War",Doubleday, Doran & Co,NY(1943),362 2)Ohart(1946),204 3)Glossary of Ord(1959),42

**Bombs, Electron.** See under Bombs, Incendiary, Extinguishing of

**Bombs, Explosive.** See under BOMBS

**Bombs, Fission.** See Vol 1,p A499-L under Atomic (or Nuclear) Bomb

**Bombs, Flash.** See Bombs, Photoflash under BOMBS

**Bombs, Fragmentation.** See under BOMBS. Brit designation is **F**

**Bombs, Fusion.** Bombs that depend upon nuclear fusion for release of their energy. See Vol 1,p A499, under Atomic(or Nuclear) Bomb

**Bombs, Gage.** See Bombs, Dummy under BOMBS

**Bombs, Gas.** See Chemical Bombs, under BOMBS

**Bombs, General Purpose(GP)** See under BOMBS

**Bombs, Glide.** See under BOMBS

**Bombs, Guided.** Aerial bombs guided during their drop, in range and/or azimuth (See also Guided Missiles)
*Ref*: Glossary of Ord(1959),43

**Bombs, Heavy Case.** Any HE bomb in which the wt of the casing is relatively large in proportion to the wt of the bursting chge
*Ref*: Glossary of Ord(1959),43

**Bombs, High Capacity(HC).** According to Ohart (Ref 1), these bombs are the same as the LC (light case) bombs with a chge wt ratio of ca 80%, such as the 4000-lb blockbuster and the depth bombs. According to Ref 2, they are GP(general purpose) bombs designed to produce max blast with chge wt ratio of more than 70%; also called "blast bombs" and "light case bombs"
*Refs*: 1)Ohart(1946),221 2)Glossary of Ord(1959), 43

**Bombs, High Explosive.** See Bombs, Explosive, under BOMBS

**Bombs, Hydrogen.** See Vol 1,p A499-L under Atomic (or Nuclear) Bomb

**Bombs, Incendiary(IB).** See Bombs, Chemical under BOMBS

**Bombs, Incendiary(Extinguishing of).** See under BOMBS, the section which follows Bombs, Disposal of

**Bombs, Infantry Training(IT).** Designation of a Brit bomb

**Bombs, Japanese Paper Balloon.** See under Balloons and Airships and their Application in War

**Bombs, Leaflet.** See under BOMBS

**Bombs, Light Case(LC).** See under BOMBS
*Note:* Designation **LC** is also used for the Brit "light case chemical bomb"

**Bombs, Magnesium.** Incendiary bombs with magnesium as burning agent
(See also Bomb, **Electron and Bombs, Chemical** under BOMBS)

**Bombs, Napalm.** See under BOMBS

**Bombs, Nuclear.** See Atomic(or Nuclear) Bomb in Vol 1,p A499-L

**Bombs, Phosphorus.** A chemical bomb filled with phosphorus, especially white phosphorus(WP). See also Bombs, Chemical(Smoke) under BOMBS

**Bombs, Photoflash.** See under BOMBS

**Bombs Pistol**(Brit). See under Bombs, British (Initiating Devices for)

**Bombs, Practice and Bomb Practice Target.** See under BOMBS

**Bombs, Robot** Missiles carrying warheads, such as the Ger V-1(see PATR 2510,p Ger 213) or a flying bomb, launched from the surface and directed in flight towards its target by an automatic pilot or other automatic devices
*Ref*: Glossary of Ord(1959),44

**Bombs, Rocket.** Aerial bombs equipped with rockets to give them added velocity and penetrating power after being dropped from an aircraft
*Ref*: Glossary of Ord(1959),44

**Bombs, Sabotage.** Expl devices used by saboteurs to damage, destroy or injure personnel or property
*Ref*: Glossary of Ord(1959),44

**Bombs, Semi-Armor-Piercing(SAP).** See under BOMBS

**Bombs, Service.** See under BOMBS

**Bombs, Smoke.** See Bombs, Chemical under BOMBS

**Bombs, Target Identification(TI).** See under BOMBS )

**Bombs, Time.** Aerial(or other) bombs that may be set to expl sometime after being dropped(or planted). Short-delay fuzed bombs are not usually classified as time bombs(see Bomb, Delayed Action)

**Bombs, Torpedo**(Bombe Torpedo in Ger). Missiles designed in Germany during the closing years of WWII. They resembled in appearance torpedos. When launched, they travelled the greater portion of the distance to the target(a ship) through the air and then would enter the water just short of the target and continue in the direction of their flight in air due to their momentum, in the same way as a torpedo. To prevent them from going too deep before deton, a relatively flat angle of entry into the water was necessary. The weapons are briefly described in TM **9-1985-2** (1953),44-5

**Bombs, Uranium.** Theoretical atomic or hydrogen bombs(See Vol 1,p A499-L) encased in Uranium, which, on deton, would be transformed into deadly radioactive dust
*Ref*: Glossary of Ord(1959),44

**Bomlit.** A Ger blasting expl manufd after WWI by Wolff & Co at Walsrode. It contained K perchlorate, AN, TNT and guncotton. Other ingredients, such as K & Na nitrates, starch, vaselin, naphthalene & other hydrocarbons, charcoal and castor oil could be used
*Ref*: A.Marshall,"Dictionary of Explosives", Churchill,London(1920),15

**Bond.** The linkage betw atoms, represented by a dot(.) or a line(-) drawn betw atoms in a constitutional formula. Nature of the bond is considered to be electrical attraction attributable to various distributions of electrons around the nuclei of bonded atoms

Bonds may be divided into *atomic* and *molecular* types. Atomic bonds, in which each atom contributed one electron, may be either *homopolar*(nonpolar) or *heteropolar*(polar). In homopolar bonds the electron pair is held equally by both atoms, so that no difference in polarity exists; while in heteropolar bonds the electron pair is held unequally, hence the atoms differ in polarity. Molecular bonds are of one type in which one atom contributes both electrons. This is the *coordinate*(semipolar) or *dative* bond. For comprehensive discussion of this subject, see L.Pauling,"The Nature of the Chemical Bond and the Structure of Molecules and Crystals", CornellUnivPress,Ithaca,1st ed(1939),429pp; 2nd ed(1940)450pp; 3rd ed(1960),644pp; L.Pauling, "La Nature de la Liaison Chimique et la Structure des Molecules et des Cristaux",PressesUniv,Paris (1949),430pp
*Refs*: 1)Hackh's(1944),137-8 2)The Van Nostrand Chemist's Dictionary, Van Nostrand,Princeton (1953),90-1

**Bond Energy.** A measure of energy reqd to disrupt a chemical bond. The definitions as used in phys chem are discussed in Refs 1 & 2
*Refs*: 1)H.A.Skinner & H.D.Springall,Nature **162**, 343-44(1948) 2)L.H.Long, Nature **162**,344-45(1948)

**"Bonderizing".** A trade mark process for furnishing a corrosion-resisting base for paint finishes on steel, Al, Zn & their alloys and die castings
*Refs*: 1)T.Lyman,Edit,"Metals Handbook", AmSoc for Metals,Cleveland(1948),733 2)CondChemDict (1950),105

**Bonding.** The act of joining together solid materials such as pieces of paper, wood, plastics & metals, by means of glue, cement or resins. Bonding can also be achieved by means of fusion, such as in *sintered metals*

See also Adhesives in Vol 1,p A102-R and Binder or Agglutinant and Bonding Agents in Vol 2
*Ref*: 1)See under Adhesives,Vol 1; and under Bind-

er or Agglutinant and under Bonding Agents, Vol 2 2)M.Packer,Monthly Progress Rept P-A2078, June 19 to July 31(1957), Contract DA-36-034-501 -ORD-67-RD(Bonding of HE's to metals)(Conf) 3)D.V.Clifford, ERDE,GtBrit,TechMemo 8/M/59 (1959)(Case bonded colloidal proplnt)

**Bonding Agents or Adhesives for Ordnance.** Bonding agents or adhesives are being used successfully in many ord applications where high strength performance applications are reqd. Numerous missiles, including Army's *Hawk, Lacrosse & Nike,* and the Air Force's *Bomark* have vital components joined by adhesives

Adhesives offer a number of advantages over mechanical means of attachment: a)they allow relatively uniform distribution of stresses over the entire bonded area b)present aerodynamically smooth surfaces c)give high strength-to-weight ratio d)can be used to join components with complex geometric configurations e)can join thin sheets f)provide effective seals against moisture fuels, chemicals & gases g)dampen vibrations and h)increase elec resistivity

Several important types of adhesives used to obtain high-strength bonds are the epoxies, epoxy -phenolics, nitrile-phenolics & vinyl-phenolics

Some specs under which these structural adhesives may be procured are: MIL-A-5090B, "Adhesive Airframe, Metal to Metal"; MIL-A-8431, "Adhesive, Heat Resistant, Airframe Structural, Metal to Metal"; MIL-A-8623A, "Adhesive, Epoxy Resin, Metal to Metal Structural Bonding"; and MIL-A-14042, "Adhesive, Epoxy"

The best approach to achieving good performance in bonded joints is to select the proper adhesive, design the joint properly for the specific application, and maintain rigid process control. One disadvantage in the use of adhesives is the absence of good non-destructive tests to determine the strength of adhesive-bonded joints in a wide variety of ord applications

Data have been obtained at PicArsn on the adhesive bonding of HE's to themselves and to other adherends. The expls investigated include 75/25 cyclotol, RDX-polystyrene & HMX-cellulose nitrate compns. Whether the bonded expl assembly was tested statically or dynamically, failure always occurred in the expl, never in the adhesive. If proper adhesives & bonding procedures are used, failure should occur in the expl

The ArmyOrd pamphlet on adhesives, ORD-P-20 -306, is a useful ref in providing addln info on bonding agents

*Refs:* 1)S.J. Lowell,"Bonding Agents for Ordnance" PATR **1685**(1948) 1a)W.T.McMichael,USP 2985055 (1955) (Bonding of booster rocket propellant) 2)M. J.Bodnar,"Bonding of Explosives to Metal",PATR **2412**(1957) 3)M.J.Bodnar et al,"Adhesive Bonding of High Explosives to Metals",PATR **2538**(1958) 3a)M.J.Bodnar & E.R.Kelly,"Adhesive Bonding of Newer Typesof Plastics, PATR **2575**(1958) 4)M. J.Bodnar et al, "Adhesives for Bonding High Explosives to Metals and Uranium to Steel",PATR **2613**(1959) 5)M.J.Bodnar,"Adhesives for Ordnance", Ordn **44**,954-5(1960)

**Bonits.** Swed military underwater expls developed by AB Bofors, Nobelkrut, Bofors. The following mixts existed before WWII:

| Composition | Bonits 1 | Bonits 2 | Bonits 3* | TNT For Comparison |
|---|---|---|---|---|
| TNT | 50 | 30 | 40 | 100 |
| RDX | 50 | 70 | 60 | - |
| Properties: | | | | |
| Loading Density, g/cc | 1.68 | 1.78 | - | 1.60-1.65 |
| Heat of Expln,cal/g | 1130 | 1200-1250 | - | 850 |
| Vel of Deton,m/sec | 7600 | 7800 | - | 6800 |
| Rel Brisance | - | 136 | - | 100 |
| Gas Vol,l/kg at NTP | - | 950 | - | 630 |
| Power by Trauzl Block,cc | - | 421 | - | 290 |

*No props given in Ref 3

During WWII some Al powd was incorporated in Bonits and this increased their efficiency for underwater explns. The Swed aluminized expls were, according to Stettbacher(Ref 2), more efficient than the Ger underwater expl of WWII, which consisted of TNT 55.7, HNDPhA 27.9 & Al 16.4%. See PATR 2510(1958),p Ger 212, under Unterwassersprengstoffe(Underwater Explosives) for addnl info on Ger expls

According to Stettbacher(Ref 2) Bonit is one of the best types of underwater expls

*Refs:* 1)Anon,"Bonit",SS **30**,332-3(1935) 2)A. Stettbacher,Protar **9**,38 & 41(1943) 3)A.Stettbacher (1948),66

**Bonocord.** See Bofors Detonating Cord

**Booby Trap.** Devices which are installed to operate against personnel in territory surrendered to the enemy are called booby traps. They are designed to function by themselves and to harass or destroy individuals or small groups of the enemy. The same device may be used for either an antipersonnel

mine or a booby trap. The classification is detd by the purpose for which the device is installed

Both the antipersonnel mine and booby trap are more important for their psychological effect on the enemy than for the number of casualties they cause. They strike unexpectedly, and often when the soldiers are relaxed in occupied areas or doing some routine task. Mines and booby traps should have infinite variety in their distribution and use and should be particularly dangerous to those who attempt to locate or remove them

In addition to std antipersonnel mines, fragmentation hand grenades, demolition blocks and other adaptable ammunition items may be used as either antipersonnel mines or booby traps by their being fitted with std firing devices. These include pull firing, pressure firing, combination firing & release firing devices(Refs 2,3 & 4)

Booby traps are also used during maneuvers and in troop training where there is the need for a "safe" booby trap. Lt Day(Ref 1) has reported the design and construction of a simple & efficient "trap" used to great advantage in training personnel. Once constructed this trap may be used over and over again. Flash simulator, illuminating simulator & whistling simulator type booby traps are special devices used to provide training in their installation and use and to encourage caution by troops exposed to booby traps set by the enemy(Ref 5)

*Refs*: 1)1st Lt J.K.Day,The Ordnance Sergeant, The OrdnSchool,APG,Md(12 July 1943),117-18 2)Anon,"Ammunition Inspection Guide",TM 9-1904 (1944),240-8 3)Ohart(1946),363 & 367 4)Anon, "Military Pyrotechnics",TM 9-1981(1951),142-7 5)Anon,"Use and Installation of Boobytraps",FM 5-31(1956)

**Books on Explosives, Propellants, Pyrotechnics and Related Items.** See list in Vol 1,p A676 and Additional List at the end of Vol 2

**Boom Powder.** A casual name for an ignition mixt designated B2-50, and used in Fuze, Grenade, Ignition,M201A1, to ignite chemical munitions, Upon ignition, the mixt produces a large number of incandescent particles. The original mixt, developed at Army Chemical Center, Md, contained: Pb chromate 60, Mg20 & Si 20%. This formulation was granulated with a NC-camphor binder. The original mixt has been replaced by a later compn consisting of: red Fe oxide 50.0, powd Ti 32.5 & powd Zr 17.5%, also granulated with a NC-camphor binder

*Ref*: Chemical Corps Specification, CmlC Formula B2-50

*Note*: Information obtained from W.W.Reaves & K.J. Carlon,Army Chemical Center, CRDL,Md

## BOOSTER

(Beiladung in Ger; Relais or Détonateur sécondaire in Fr; Carica di rinforzo, Carica d'accencione or Accelerante di esplosione in Ital; Promezhutochnyi detonator in Rus; Carga de inflamación in Span)

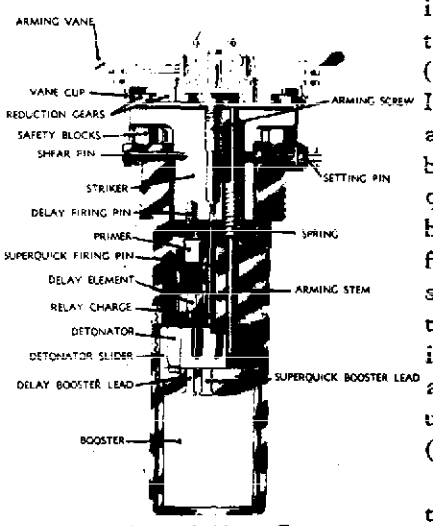
According to Marshall 2(1917),527, the Brit name is *renfort* or *booster*. Glossary of Ord(1959), 133 calls the Brit booster or auxiliary detonating fuze the *gaine*, but it seems that this term must be applied only to the booster container and not to the entire booster. All&EnExpl(1946),p 165, calls it *exploder*, but judging by drawings of some Brit fuzes, the exploder consists of booster and detonator chges. The term *magazine* seems to mean the same as *exploder container* or *gaine*. In some Jap fuzes, the term gaine was used for the HE container located betw the detonator and the booster(see Fig 101,p136 in Ref 14 and Fig 304,p 381 in Ref 15), but in most Jap ammo the term gaine is reserved for the booster container.

When a HE, such as TNT, PA, Amatol, Comp B, etc is used as the main(bursting) chge in a missile (shell, bomb, rocket, torpedo) and is not sensitive enough to be activated by ordinary detonators, an expl intermediate in sensitivity betw initiating and main expl chges is introduced betw them. This expl (such as pressed RDX, Tetryl, PETN, HNDPhA, etc), called *booster explosive*, will readily detonate from the action of the initiator and develop enough energy to ensure high-order detonation in the less sensitive main chge. The same effect can be obtained by using larger amts of initiating (primary) expls(such as MF, LA, or Tetracene) but this is not advisable because their high sensitivity to shock and friction makes them very dangerous to handle in large amts, as well as rendering the round more susceptible to premature expln. Also, they are much more expensive and more difficult to manuf than expls like Tetryl

Press-loaded Tetryl has been used in most US boosters, but RDX is used in some newer types(Ref 20). One US bomb fuze, namely the M111A2 Nose Fuze, contained a BkPdr booster(Ref 7,p 270). Some US Navy boosters contained pressed PA(Ref 8,p 93). The booster housing(container) may be in the shape of a cup or of a long cylinder closed at

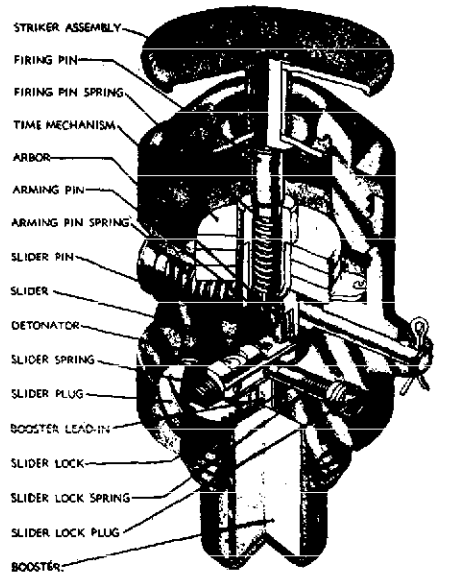
Body & Booster Assembly US Bomb Nose Fuze M171

the bottom. The containers are usually screwed directly to the fuze and become an intergral part of it or they may be imbedded separately in the main chge of a missile; then the detonator is imbedded in the booster chge. Boosters that have a self-arming feature are considered as *auxiliary fuzes*. If an ordinary booster is not sufficient to guarantee high-order deton of a very large bomb, an addl booster, called *auxiliary booster* (sometimes called *sub-booster*) is attached to the main boosters (Ref 7,p 249). In many cases an auxiliary booster is required to ensure high-order deton for very insensitive expls or to do the same in the event that a bomb breaks upon impact (See Figs)




US Bomb Nose Fuze Arming Type With Booster

During WWII the British used either compressed Tetryl or a combination of compressed Tetryl and TNT(Ref 8,p 165), but prior to this they used compressed PA(Ref 4). The info about their current uses is classified



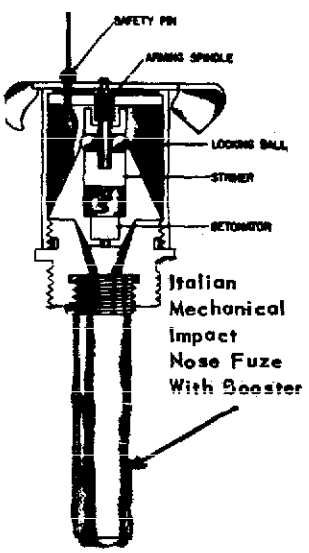

US Bomb, Nose Fuze With Booster

The French and Japanese used compressed PA. The Russians, as late as WWI, used pressed dry Guncotton as boosters in warheads of some torpedoes with wet guncotton as bursting chge and pressed TNT for shells contg cast TNT. They also used PA

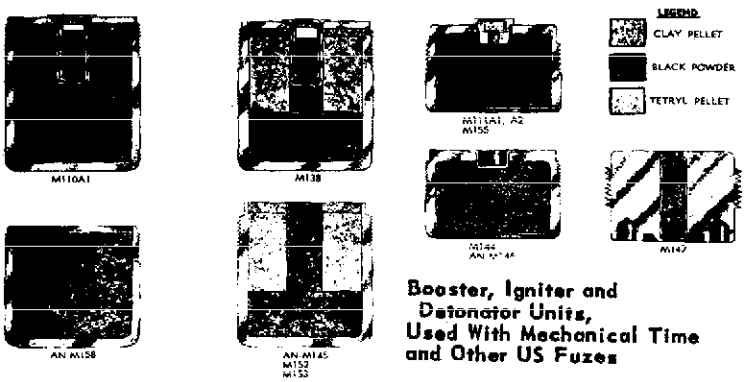
The Italian boosters used during WWII in HE shells were of two types:

a)The older system consisted of a metal tube, contg compressed Ballistite and provided with a flash hole at each end. The tube was fitted below with a PDF(point detonating fuze) and had under it a larger chge of Ballistite contained in a metal tube with a flash hole at the top only

b)The later system, called *detonatore ad alto esplosivo, M35 o M38*, used in shaped

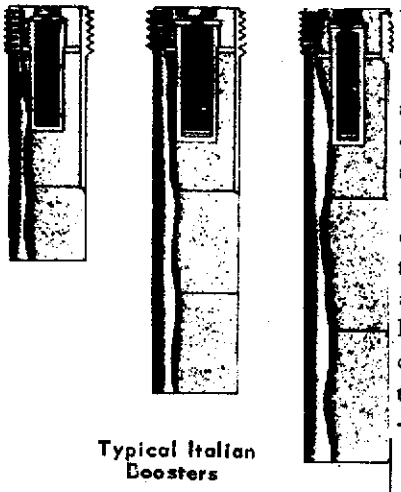



Italian Mechanical Impact Nose Fuze With Booster



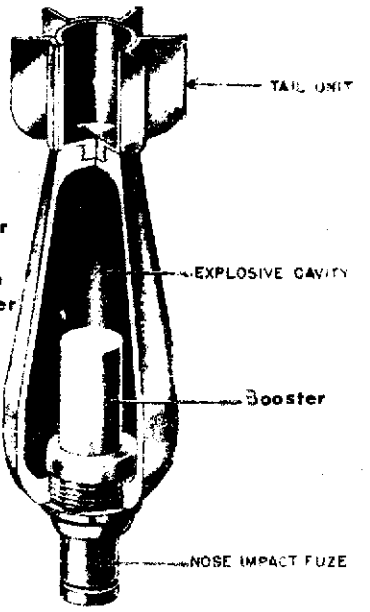

Booster, Igniter and Detonator Units, Used With Mechanical Time and Other US Fuzes

-chge projs, consisted of two parts, an upper and a lower. The upper part, which was fitted(by means of a collar) below the regular PDF, consisted of an Al cylinder with a tube inserted in it. The tube contained a layer of RDX(serving as a base chge) and a layer of LA(serving as a primary chge). The lower part of the booster contained several pellets of TNT wrapped in oil paper (Ref 16,pp 61-3 and Figs 72 & 73)



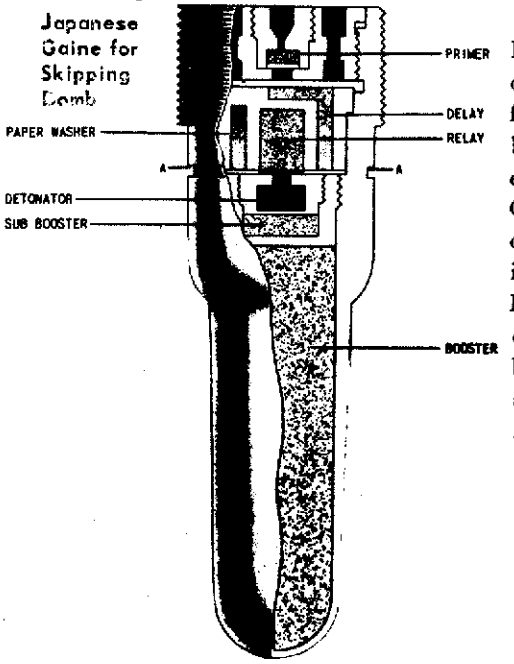
Typical Italian Boosters

The Italian *booster container* used during WWII in bombs was either a long or short type. The long booster consisted of a tube 7.5" long and 1.3" external diam, closed at one end; the short type was a similar tube 4.8" long and 1.3" ext diam. The long tube was screw-threaded at the open end to take an adapter and contained two compressed blocks of TNT below the adapter; the upper block was recessed to take a booster. The short booster was similar but contained a smaller chge. Different types of adapters were fitted to the booster to give delay action, or different length projections of the auxiliary booster which fitted into the booster proper. The *auxiliary booster* was the same for both types. It consisted of an Al tube, the top of which was threaded to a steel plug which fitted into the adapter. Above the auxiliary booster, the booster lead-in pellet was located and it had a relay or delay pellet below it. For the definition of *adapter-booster*




French 1-kg Mortar Bomb With Nose Fuze and Booster

See Vol 1,p 102-L

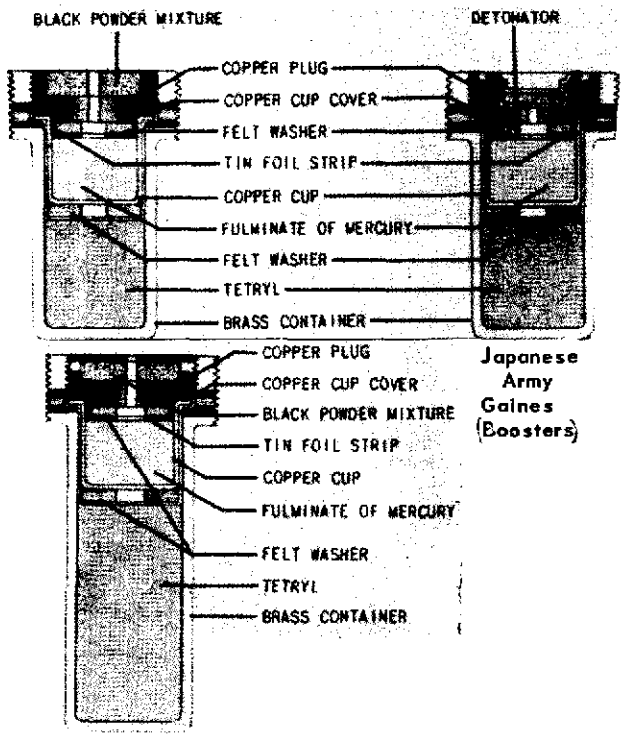



Japanese Gaine for Skipping Bomb

Illustrations of some foreign boosters, except German ones, are included. Illustrations of Ger boosters are given in Refs 12,13 & 17

*Refs*: 1)Marshall **2**(1917),527-8(Boosters or "renforts" consisting of TNT loaded in brass tubes 4" long and of a diam slightly larger than the detonators) 2)F.Olsen,ArOrdn **3**,269-72(1923) (Brit boosters prior to WWI contained loose PA. This was gradually replaced during WWI by Tetryl, known in GtBrit as CE. When the US entered the war, it adopted Brit boosters) 3)Marshall **3**(1932), 162-3 (Brit Army *gaine* was a strong steel tube ca 3" long & 1/4" wall thickness, which was screwed into the mouth of a shell. At the top there was a

pellet of BkPdr with an axial perforation. This was ignited by the flash from a fuse, which was screwed




over the gaine. This pellet passed a more powerful flash to an open capsule contg MF situated immediately over two tetryl pellets. The bottom of the gaine was closed with a cap strong enough to withstand the considerable forces that arose when the shell was fired from a gun. The shell was filled with Amatol the center of which contained a long cylindrical cavity lined with cast TNT. A bag with cryst TNT was placed on the bottom of the cavity and the Tetryl end of the gaine was pressed firmly onto the TNT. With this arrangement, MF detonated Tetryl from which the deton wave passed to cryst TNT, then to cast TNT and finally to the main chge of Amatol) 4)Marshall **3**(1932), 172-3 5)Hayes(1938),6,39,595-6 & 606 5a)W.R. Tomlinson,Jr,PATR **1311**(1943) (Some foreign booster and HE's compns) 6)Anon,"Ammunition Inspection Guide", TM **9-1904**(1944),19,124-30,267,399-403, 444,473,495-7 & 569 6a)L.H.Eriksen,PATR **1446** (1944) (Some foreign booster and HE's compns) 7)Ohart(1946),19-20,36,122,165-9,217-19,225-7,249 262-3,270,281 & 338 8)All&EnExpl(1946),163-6 8a)P.F.Schaeffer,PATR **1677**(1948)(Development of improved boosters) 9)Anon,"Artillery Ammunition",TM **9-1901**(1950),310 & 369-76 10)L.Médard, MP **33**,339(1951) ("Relais" of pressed 95/5 mixt of PETN/Mononitronaphthalene, d1.60, was found to be satisfactory; as was also the "relais" of cryst PA pressed to d 1.10 in Kraft paper tubes 30mm in diam) 11)Anon,"British Explosive Ordnance",TM **9-1985-1**(1953),(Conf) 12)Anon,"German Explosive Ordnance",TM **9-1985-2**(1953),125,138,156,179,185 & 188(Bomb boosters) 13)Ditto,TM **9-1985-3**(1953), 390,400-1,406-7,410-22,425,427,429-35,437-8,440, 442-5,450-8,460-1,466-8,472-3,482,488-90,500,511, 516-18,521-2,552 & 562(Shell boosters) 14)Anon, "Japanese Explosive Ordnance",TM **9-1985-4**(1953), 22,122,125-6,128-33,136-7,139-43,145-148,150,152, 158,173,175 & 190-201(Bomb boosters) 15)Ditto, TM **9-1985-5**(1953),281-3,304,308,319-20,322-31, 336;340-4,373,378,380-1,384-9,391-8,400-5,409,419 -23,436,461,468,470,473-6,481-2,485,489-92,497-9, 503,506-8,521-5,528-32 & 541-2(Shell boosters) 16)Anon,"Italian and French Explosive Ordnance", TM **9-1985-6**(1953),3,8,28,39,44,48 & 52(Ital bomb boosters; 61-3 & 81(Ital shell boosters); 178-9, 183,190,196 & 205(French bomb boosters) 17)PATR **2510**(1958),pp Ger 20-1 18)US Specifications: MIL-B-12739(Booster, auxiliary, T33E1; loading, assembly & packing); MIL-B-14316)(Booster,M21A4 & M25; loading,assembly & packing); MIL-B-20474 & MIL-B-20360(Booster,M22; metal parts for, loading,assembly & packing); MIL-B-20492 & MIL-B-20359(Booster,M24 & M24B1; metal parts for, loading, assembly & packing); MIL-B-20394 & MIL-B-20392(Booster,M25; metal parts for, loading, assembly & packing); MIL-B 11507A(Booster,M120; loading, assembly & packing); MIL-B-13675(Booster,M123; loading, assembly & packing); MIL-B-13674 & MIL-B-12830 (Booster,T35E7; metal parts for and loading, assembly & packing) MIL-B-11627 & MIL-B-11615 (Booster,T36E2; metal parts for and loading,assembly and packing) MIL-B-10997[Booster,T1208 (N120); metal parts for] 19)A.B.Schilling,PicArsn; private communication(1962) 20)P.Varrato,PicArsn; private communication(1962)

**Booster Rocket.** Any high-thrust unit or assembly that fires at take-off to get a missile(such as a rocket,bomb,shell) or an unmanned or manned aircraft, to which it is attached, started along its trajectory. Usually, a booster rocket produces a much greater thrust than the 2nd stage or sustained power plant of a rocket. Booster rockets are usually propelled by a solid propellant(such as in the Nike -Ajax missile) but liq proplnts are also used. The booster rocket should not be confused with ATO, JATO or RATO engines although there is a considerable similarity in design. A liquid-propelled booster rocket is used when the requirements are more extensive than normally available from solid-pro-

pelled units. The term *first-stage engine* is recommended for those designs where the booster unit is usually large and is completely expended during the 1st stage operation
*Refs*: 1)A.J.Zaehringer, "Solid Propellant Rockets", AmerRocketCo, Wyandotte,Mich(1955),2 2)Rocket-Encycl(1959),54-8

**Booster Sensitivity Test.** See Vol 1,p VIII. More detailed description was given by L.Goodman in "Physical Testing of Explosives", Part III,OSRD **2746**(1945),6-7

**Boracitol.** A HE compn listed in Ordn Safety Manual ORDM **7-224**(1958),Tables 1904 & 1905,pp 19-3 & 19-15 as Storage Compatibility Group L and Explosive Hazard Class 9. The compn & props of this HE could not be found in std ref works, reports or in Ord manuals

**Boranes.** See Boron Hydrides

**Borates.** A general term for salts of acids based on boron, such as: *metaboric* $HBO_2$, *perboric* $HBO_3$, *tetra-* or *pyroboric* $H_2B_4O_7$, *boric or orthoboric* $H_3BO_3$ and others. Props of various borates are given in Refs 1,3,5,6 & 7 and their uses in some pyrotechnic compns are listed in Ref 8

Following is the list of some borates:
*Ammonium Borate* (Ammonium Acid Tetraborate), $(NH_4)HB_4O_7.3H_2O$, mw 228.37; col crysts, mp decomp, d 2.6; used as a fire-retardant (Ref 7, p 71 & Ref 4)
*Butyl Borate*(Tributyl Borate), $(C_4H_9)_3BO_3$, mw 230.16, col liq, bp 232.4°, d 0.855-0.857, flash p 185°F(open cup), $n_D$ 1.4071 at 25°(Ref 7,p1159). Its use as an ingredient of smoke-producing compns was patented by DeMent(Ref 8) See also Ref5,p1198
*Calcium Metaborate*, $Ca(BO_2)_2$; mw 125.72, col rhmb or long flat plates, mp 1154°(Ref 5,p 424)
*Cupric Metaborate*, $Cu(BO_2)_2$; mw 149.18; bl-grn crysts, d 3.859(Ref 5,p 515)
*Ethyl Borate*(Triethyl Borate or Triethoxyboron) $(C_2H_5)_3BO_3$; mw 146.00; col liq with mild odor, bp 120°, flash p 52°F, d 0.864 at 26.5°; toxicity details unknown(Ref 5,p 668 & Ref 7,p 459). Its use in smoke-producing compns was patented by DeMent(Ref 8)
*Lead Metaborate*, $Pb(BO_2)_2.H_2O$; mw 310.87; wh powd, d 5.598(anhyd) (Ref 5,816)
*Magnesium Orthoborate*, $Mg_3(BO_3)_2$; mw 190.60; rhmb col crysts, d 2.99 at 21°(Ref 5,p 841)
*Potassium Metaborate*, $KBO_2$; mw 81.92; col crysts, mp 947-50°(Ref 5,1037)
*Sodium Tetraborate*, $Na_2B_4O_7$; mw 201.27; wh crysts mp 741°, bp 1575°(dec), d 2.367(Ref 5,1129); very good fire retardant(Ref 4) (See Borax) (See also Spec MIL-S-11159 amd Ref 4a for methods of analysis)
*Trimethyl Borate*, $(CH_3)_3BO_3$; mw 103.92; liq, fr p -29°, bp 68.7, flash p 32°F, d 0.923, vap press 90mm at 60°F; decomposes in w (Ref 6)
*Zinc Borate*, $3ZnO.2B_2O_3$; mw 383.42; wh amor powd or triclinic crysts, mp 980°, d 3.64(amor) & 4.22(cryst); used as a fungicide(Ref 5,1267)

Sax(Ref 5,377) reports that borates in general are not highly toxic and therefore not considered as industrial poisons. Sodium borate is used in medicine but accidental poisoning due to ingestion of borates or boric acid has often occurred
*Refs:* 1)Mellor **5**(1924),47 & 65 2)Hackh's(1944), 138 3)Kirk & Othmer **2**(1948),600ff 4)P.Bernhard, IndVernice(Milan) **7**,113-18(in Ger) & 119-21(in Ital) (1953); CA **47**,11755(1953) 4a)S.Kaye,PATR **1947** (1953)(Determination of purity of Na tetraborate by titration in nonaqueous medium) 5)Sax(1957),377 & 1198 6)M.H.Crompton & J.E.Reed, "Some Properties of High Energy Fuel Chemical Materials", Olin Mathieson Chem Corp(1959),p117 7)Cond-Chem Dict(1961),459 & 1159 8)J.DeMent,USP 2995526(1961),p27

**Borax** occurs naturally as *tincal* in the dried-up inland lakes of India, Tibet & California. Native tincal contains ca 55% *Sodium Tetraborate Decahydrate*, $Na_2B_4O_7.10H_2O$; mw 381.44, mp 75° (loses $8H_2O$ at 60° & $10H_2O$ at 200°), d 1.69-1.72(Ref 6); sl sol in cold w, v sol in hot w. If a satd soln be allowed to cool above 62°, octahedral crysts of the *pentahydrate*, $Na_2B_4O_7.5H_2O$ separate

Since 1926 when the mineral *kernite*($Na_2B_4O_7.4H_2O$) was discovered in Searle's Lake,Calif, it has been almost the sole source of borax in the USA. Kernite is first extracted with hot w which dissolves borax; any silica in soln is pptd and the hot filtrate, after dilution, is treated with an oxidg agent to destroy coloring matter. After further filtration, borax is obtd by crystn(Refs 3 & 4)

When heated, borax fuses, loses w and swells into a wh porous mass. Finally borax melts(anhyd powd at 561°) and on cooling forms a clear glass. Borax "beads" fused in a loop of Pt wire are used as tests for oxides which dissolve in the bead and show characteristic colors

Large quantities of borax are used in the manuf of enamels, glass, soap, drying oils and as cleaning & stiffening agents in laundering, as a flux in soldering & brazing and as an antiseptic(Ref 2,

3 & 4). Pearcy(Ref 1) used borax, together with NaCl(or KCl) and $KNO_3$, as an additive to NG-NC expls to render them safe against fire damp. Carbonaceous matter was avoided as far as possible in such expls. One expl compn contd NG 42.5, NC 2.5, $KNO_3$ 20, borax 20 & NaCl 15%

US Specification requirements for military uses of borax are given in Refs 5 & 7

*Refs*: 1)A.C.Pearcy,BritP 7647(1914) & CA **9**, 2593(1915) 2)Hackh's(1944),779 3)Mellor(1946), 660-1 4)Partington(1950),652 5)USSpec SS-B-611A (1952)(Borax, sodium borate) 6)Sax(1957),374 7)USSpec SS-S-535A(1958) (Sodium borate, decahydrate, tech borax) 8)R.F.Gould,Edit "Borax to Boranes",Advances in Chemistry Series No 32 American Chemical Society,Washington,DC(1961), 240pp

**Borazole**, $B_3N_3H_6$; mw 80.53, N 52.18%; col liq, frp -58°, bp 53°, d 0.824 at 0°; some other physical props are given by Eddy et al(Ref 5); can be prepd by interaction of $LiBH_4$ & $NH_4Cl$ in the absence of solvs at mod high temps(Ref 3). Although the yields(30-35%) are of the same order of magnitude as those obtd in earlier procedures, this method, according to Schaeffer et al(Ref 3), is more convenient in that it does not use high pressure & high vac app and it does not req the use of $B_2H_6$. A four-step procedure involving the reaction of $B_2H_6$ with liq $NH_3$ to give borazole is described by Rollier(Ref 4) who also studied its structure

Sax(Ref 6) considers this compd to be moderately high in toxicity and a dangerous fire hazard, as chem reaction can produce spontaneously flammable gases

Schaeffer et al(Ref 4) found that $NH_4Cl$ causes extensive decompn of borazole at 275° and above. The compds $LiBH_4$ & $B_2H_6$ do not react appreciably with it. Boron halides react to give mono & dichloro- or bromoborazoles, some of the physical props of which are described by Schaeffer et al. Some borazole compds are described by Wiberg et al(Ref 1), and an exhaustive review of their mol structure, formation, phys & chem props is also given by Wiberg(Ref 2)

*Refs*: 1)E.Wiberg et al,Z AnorgChem **256**,177 -216(1948) & 257, 133-44(1948); CA **43**,5690(1949) 2)E.Wiberg,Naturwissenschaften **35**,182-8 & 212 -18(1948); CA **44**,2882(1950) 3)G.W.Schaeffer et al,JACS **73**,1612-14(1951) & CA **45**,6951(1951) 4)M.A.Rollier,Gazz **81**,272-5(1951) & CA **46**,3444 (1952) 5)L.B.Eddy et al, JACS **77**,2105-6(1955) & CA **49**,9993(1955) 6)Sax(1957),374

**Bore**(noun). The interior portion of a gun barrel or tube which is in front of the breechblock, including powd chamber, shot chamber, slopes and the rifled portion of the tube(see also Barrel, Gun)

*Ref*: 1)Glossary of Ord(1959),45 2)Webster's Unabridged Dictionary(1961),255

**Bore Diameter** is the diam of the gun bore prior to cutting the grooves therein. Since the latter are 0.003 to 0.005" in depth(sometimes up to 0.010"), bore diam is always materially less than the "groove diam"(qv). Those portions of the bore not cut away in fashioning the grooves, and hence left projecting upward betw the grooves like ribbons of metal, are called *lands*. Thus, another definition of bore diam is the distance across the *lands*, that is, from the surface of one *land* to that of another directly opposite

*Refs*: 1)Hayes(1938),159 & 194 2)Glossary of Ord(1959),45,53 & 167

**Boreholes or Blast Holes**(Trous de mine in Fr). Holes made by boring or drilling, for the purpose of confining a blasting chge making it possible for the expl to develop max efficiency in breaking the surrounding material, are called boreholes or blast holes. These holes vary over a wide range of size and type and are drilled, by many different kinds of equipment, in all conceivable directions from straight up to straight down. Small holes (from 1 to 2.5" diam and up to 30ft long), in rock are usually drilled with percussion type machines operated by compressed air. Similiar holes in soft material such as salt, potash, gypsum & coal are drilled with augur machines, either mechanically driven or air operated

For larger holes in rock(up to 3.5" diam and up to 40ft in length),the compressed air operated wagon drill is generally used. With the above exceptions, practically all blasting for raw material production above ground involves the use of large diam holes. Most quarries, open pit mines, ore mines & coal strippings are in this catagory. Blast holes in such operations range from 5 to 9", with a few locations as low as 4" and as high as 12". These holes are vertical in most cases except in bituminous coal strippings where horizontal auger holes(in the "high wall") are commonly used. Some types of rock formations can be blasted most economically by the use of *coyote tunnels*(qv)

*Refs*: 1)Daniel(1902),606-9 2)Blasters' Hdb (1952),163-5

**Bore Prematures.** See Explosions, Premature

**Bore Resistance.** A term used in Interior Ballistics which designates resistance to movements of a projectile that takes place in the bore of a gun after the rotating band is engraved by the rifling
*Refs*: 1)Corner,Ballistics(1950),213-25 2)SACMS, Ballistics(1951),115

**Boresafe.** This term is applied to a projectile when all of its detong elements are positively separated from the booster by some form of interruption while in the bore of a weapon
*Ref*: Anon,"Ammunition Inspection Guide",TM **9-1904** (1944),322

**Bore Safe Fuze.** Certain fuzes are considered to be boresafe(detonator safe) if the expl train is interrupted so that, while the projectile is still in the bore of the weapon, premature action of the bursting chge is prevented should any one of the more sensitive elements (primer or detonator) accidently function(Refs 1,2, & 3). This term is sometimes applied to fuzes that, due to design, have never functioned prematurely (Ref 2)
*Refs*: 1)Anon,"Ammunition General",TM **9-1900** (1946),107;(1956),134 2)Ohart(1946),123 3)Anon,"Artillery Ammunition", TM **9-1901**(1950), 243

**Boric Acid**(Boracic Acid or Orthoboric Acid), $H_3BO_3$; mw 61.84; wh triclinic crysts or powd, mp 185°(dec), loses $1.5H_2O$ at 300° d 1.435 at 15°; sl sol in cold w; more readily sol in hot w, alc or glycerin; made from borax by adding HCl or $H_2SO_4$ to a hot concd soln and crystg the prod by cooling(Refs 1,2 & 5). Sax(Ref 7) considers boric acid as moderately toxic but reports that fatal poisoning of children has been caused by accidental substitution of boric acid for powd milk. The fatal dose of orally ingested boric acid for an adult is somewhat more than 15 or 20g and for an infant 5 to 6g

Several boric acids are known(at least in the form of salts), all derived from boron trioxide, with varying amts of water:
*Orthoboric acid* $H_3BO_3$ or $B_2O_3.3H_2O$
*Metaboric acid* $HBO_2$ or $B_2O_3.H_2O$
*Tetraboric acid* $H_2B_4O_7$ or $2B_2O_3.H_2O$

Of the free acids, orthoboric is the only important one. A large proportion of the world's supply of boric acid is now made from the naturally occurring mineral *colemanite*($Ca_2B_6O_{11}.5H_2O$)(Ref 3) and other minerals(Ref 6)

Boric acid is used in medicine as an antiseptic and large quantities have been used as a food preservative. Its use for this purpose is now prohibited in many countries. Boric acid is also used in the manuf of glazes, particularly for enamels to be used on metals(Ref 3). Boric acid has been used in expls, such as Boritines(qv). Its use in smoke-producing compns was patented by DeMent(Ref 10)
*Refs*: 1)Mellor **5**(1924),47ff 2)Hackh's(1944),138 3)Mellor(1946),659 4)Kirk & Othmer **2**(1948),602 5)Partington(1950),653 6)Faith,Keyes & Clark (1957),161-4 7)Sax(1957),375 8)M.H.Crompton & J.E.Reed,"Some Properties of High Energy Fuel Chemical Materials,Olin Mathieson(1959),p10 9)US Spec MS-36038(May 1960) 10)J.DeMent,USP 2995526(1961),p 28

**Borides** are binary compds of neg boron with a more positive element or radical of the type $M_3B$ or $BR_3$(Ref 2). They are prepd by electrolysis of corresponding borates with addn of fluorides at about 1000°. Andrieux(Ref 4) successfully applied this method to making $TiB_2$, $LaB_6$, $NdB_6$, $GdB_6$, $YB_6$, $ErB_6$, $ThB_5$, $VB_2$, $Cr_3B_2$, $UB_4$, MnB, $ZrB_4$, $TaB_2$, $CbB_2$, MoB & WB. Calcium boride, ($CaB_6$), is made by electrolyzing 2 $CaB_2O_4$ + CaF in a small carbon crucible; borides of other alkaline earths are made in the same way. For making Ce borides, it is more advantageous to use alk earth borates with a small amt of $CeO_2$(Ref 4). The mechanism of electrolytic prepn of borides of difficultly fusible metals was studied by Meerson & Smirnov(Ref 10). Montgomery(Ref 6) patented a process for the making of cryst borides by heating $CB_4$ with one or more of the elements (Ti, V, Cr, Zr, Nb, Mo, Hf, Ta & W) at 1900° under a press of 1000 lbs/in². Meerson & Samsonov (Ref 9) prepd borides of high-melting metals from mixts of metal oxide(of Ti, Zr, Nb, Ta & W) with $CB_4$ & lampblack by a vacuum-thermal process

A review of the chemistry of borides has been reported by Brauer(Ref 5), Kieffer(Ref 7) and Samsonov & Markovskii(Ref 11)

Richardson(Ref 8) in a review of the application of borides and other materials noted that boride -type materials, although brittle, may be useful as components of rocket engines
*Refs*: 1)Mellor **5**(1924),23ff 2)Hackh's(1944),138 3)Kirk & Othmer **2**(1948),592 4)J.L.Andrieux,Rev Mét **45**,49-59(1948); JFourElec **57**,No 3,54(1948) &

CA **42**,8089(1948) 5)G.Brauer, FIAT RevGerSci 1939-1946, InorgChem Pt II, **1948**, 100-8 & CA **43**,3329(1949) 6)H.R.Montgomery, USP 2613154(1952) & CA **47**,2674(1953) 7)R.Kieffer, PlanseeP roc **1952**,268-96(1953) & CA **4710438** (1953) 8)L.R.Richardson,Sr,AmerCeramBull **33**, 135-7(1954) & CA **48**,8506(1954) 9)G.A.Meerson & G.V.Samsonov,ZhPriklKhim **27**,1115-20(1954) & CA **49**,6757(1955); Ibid **27**,1053-7(1954) (English translation) & CA **50**,6988(1956) 10)G.A.Meerson & M.P.Smirnov,KhimRedkikhElementov,AkadNauk (Russia)InstObshchei i NeorgKhim **1955**,No 2, 130-47 & CA **50**,3122(1956) 11)G.V.Samsonov & L.Ya. Markovskii,UspekhiKhim **25**,190-241 (1956) & CA **50**,8359(1956)

**Boring, Use of Explosives in.** Boring operations may be considerably facilitated if expls are used to destroy hard objects, such as stones, broken boring bits, etc obstructing the progress of the drill. One of the first applications of expls for such operations was made in France by Brunet and the method was described by Haton de la Coupillière in Annales des Mines [7] **16**,5(1879)

Lipmann, of France,facilitated drilling for the foundation of a column by first softening the ground by exploding small charges over multi-tubular cutters. Jandin used a similar idea during the construction of Palma del Rio bridge over Gudalquivir, Spain. Roberts of the USA made a fortune in the Pennsylvania oil fields from the idea of exploding charges of NG or dynamite near the bottom of completely exhausted oil wells. For this, he either poured some NG into the well or lowered into the well a tin cartridge of dynamite provided with a blasting cap. Explosion in both cases was initiated by dropping a weight (called a "go-devil") from the top of the well. This method caused the ground near the bottom of the well to crack and if there were any oil in the vicinity, it would flow toward the bore hole thus rejuvenating the exhausted well(Ref 1)

The method used by Roberts is known now as "well-shooting" and is practiced not only in petroleum, but also in water and gas wells. As NG is very dangerous to handle, many premature explns took place in the past, causing the loss of life and property. Because of these facts, the DuPont Co has worked for years towards the complete elimination of liq NG in its well shooting activities. This goal was finally achieved beginning in 1951 and NG has now been replaced by a series of better and safer expls, such as "DuPont SNG" (solid nitroglycerin), "Hi-Velocity" Gelatin, "Red -Cross Extra", "EL-389-B" (desensitized NG), "SOWE"(special oil well expl) No 1 & No 3 and "EL-431-A"(cast, non NG expl). Methods of well shooting are described in Ref 2,pp 443-50

Digging of pole holes(Ref 2,pp 422-3), excavation (Ref 2,p 365), ditching (Ref 2,p 379) and some other drilling operns can be facilitated by the use of expls

(See also Seismic Exploration or Prospecting)

*Refs*: 1)Daniel(1902),722, under "Sondage" 2)Blasters' Hdb(1952), 365-410, 417-24,& 443 -50

**Boritines.** Safety expls, patented in Fr in 1887 by Turpin, consisted of: a)NG 37.5, kieselguhr 12.5 & boric acid 50% and b)$KClO_3$ 35, boric acid 50, DNB 5, charcoal 5 & coal tar 5%

*Ref*: Daniel(1902),77

**Borland Powder.** An expl prepd in England by impregnating NC with a soln of K or Na bichromate, drying and treating it with a soln of a Ba salt. This caused formation of $BaCr_2O_7$ which deposited inside and outside the NC fibers. The resulting mass produced a smokeless powd which could also be gelatinized

*Ref*: Daniel(1902),78

**Borland's Method of Manufacturing Smokeless Powder.** In 1901, Mr Borland, Director of EC Powd Co, Ltd, England, invented a procedure in which NC was gelatinized by an emulsion contg MeOH, acet, camphor, paraffin oil & benz or ligroin. The vol solv was removed by moist air heated at 65.5° . The moisture in the air was used to prevent formation of static electricity

*Ref*: Daniel(1902),78

**Borlinetto Powder.** An expl compn patented in 1867: PA 35.1, $NaNO_3$ 35.1 & $K_2CrO_4$ 29.8%

*Refs:* 1)Daniel(1902),79 & 626 2)Pérez Ara (1945), 220-1

**Borneol** (Also called Bornyl Alcohol, Baras Camphor, Borneo-Camphor, 2-Camphanol, d--Camphyl Alcohol, 2-Hydroxy-Camphane or Sumatras Camphor), $C_{10}H_{17}OH$; mw 154.24, O 10.37%; transparent hex lfts, mp 108°, bp 212°, flash p 302°F (Closed Cup), d 1.011 at 20°; sol in alc or eth; v sl sol in w. It is a terpene either obtained from the *Dryobalanops Camphora* fruit or prepd synthetically. It is used

in perfumery, celluloid manuf & in medicine as an antiseptic or stimulant
*Ref*: 1)Beil **6**,72,(47) & [80] 2)Hackh's(1944), 139 3)Sax(1957),375

**Börnstein, Ernst** (1854-1932). Ger professor of chemistry at Strassburg and Berlin. His doctor's thesis was a contribution to research on bitolyl. He did important work on the decompn of coal and other solid fuels. His brother, *Richard Börnstein*, is co-author of Landolt-Börnstein
*Ref*: F.Frank, AngChem **45**,289(1932)

## BORON, ITS COMPOUNDS, EXPLOSIVES, FUELS AND PROPELLANTS

**Boron**(Bor in Ger & Rus, Bore in Fr, Boro in Ital & Span), B, at wt 10.82; occurs in two forms: blk monoclinic crysts & yel or brn amor powd; mp 2040°, bp 3930°, d 2.33(cryst), 1.73(amor); sol in nitric and sulfuric acids and in most molten metals; insol in w, alc, ether & solns of caustic alkalies. The element boron was isolated in 1808 by Gay-Lussac & Thenard who reduced boron oxide($B_2O_3$) with K by heating it in an iron tube. Sir Humphrey Davey independently obtd the same product and called the element "boron". This element is not found free in nature, but occurs in the form of borates & boric acid. It can be prepd by the reduction of the oxide, borates or boron halides

Boron is one of a group of elements, such as Pb, Mn & As, which affects the central nervous system. It is a cumulative poison causing depression of circulation, persistent vomiting & diarrhea, followed by profound shock and coma. Care should be observed in applying boron ointments & dressings over large areas of the body where the skin has been destroyed. It can be absorbed by the body in this way and by irrigation of body cavities with solns contg boron. It is an expln hazard in the form of *dust*, which ignites on contact with air (Ref 8)

Boron is the only element in Group III that is nonmetallic in behavior. It is unaffected by air at RT but at higher temps it forms the nitride(BN) and the oxide($B_2O_3$). Boron reacts with F at RT amd with Cl, Br & S upon heating. It does not react with H even when heated to red heat

Elemental boron is used chiefly in the metal industry, such as a deoxidizer & degasifier and for increasing the hardness of steels. Boron and its compds are used as high energy fuels in expl & proplnt compns. Uses of boron in blasting caps are listed in Refs 6a, 6b & 9b. An igniter compn and delay compns using amorphous B are listed by Ellern(Ref 14a)
(See also Boron Explosives, Boron Hydride Fuels, Boronites, Boron Solid Propellants and Borotorbex)
*Refs*: 1)Mellor **5**(1924), 1-23 2)Gmelin,Syst Nr **13** (1926),1-53 & (1954),1-96 3)Thorpe **2**(1938),34-40 4)Hackh's(1944),139 5)Kirk & Othmer **2**(1948), 584-88 6)Partington(1950),654 6a)G.A.Noddin & C.P.Spaeth, USP 2717204 (1955) & CA **50**,2174 (1956) (Use of B in elec blasting caps) 6b)Ibid, GerP 941473(1956) & CA **52**,15072(1958) (Use of B in primers with delay action) 6c)Coll, "Soviet Research in Boron Chemistry 1949-1956, "English Translation, Consultants Bureau, Inc,NY (1956) 7)G.A.W.Boehm, Fortune(Dec 1957),166 8)Sax(1957),376-7 9)Experiment,Inc, "Combustion of Elemental Boron", TM **1038**(Feb thru April 1958) TM **1090**(Aug thru Oct 1958) and TM **1094**(Nov 1958); thru Jan 1959) 9a)H.Williams & W.A.Gey, USP 2900242(1959) & CA **53**,22957(1959) (Use of B in ignition compns) 10)W.E.Bost, "Chemistry of Boron and Boron Compounds. A Literary Survey", AEC, TID **3523**(1959) 11)USCongress, House Committee on Science and Astronautics, "Boron High-Energy Fuels", 86th Congress, First Session, Report No **1191**(1959) 11a)M.H.Crompton & J.E.Reed, "Some Properties of High Energy Fuel Chemical Materials," Olin Mathieson(1959),p 12 12)F.A.Cotton, "Chemistry of Boron", MIT Status Reports No **1** to No **7** (1959) to 1961) 13)D.N.Williams, "The Properties of Boron", Battelle Memorial Inst, DMIC Memo **41** (1960) (OTS PB No **161191**) 14)J.A.Kohn, W.F. Nye & G.K.Gaulé, Edits, "Boron: Synthesis, Structure and Properties", PlenumPress,NY(1960) (Procee dings of Conference on Boron sponsored by US Army Signal Corps Research and Development Laboratory, Sept 1959) 14a)H.Ellern, "Modern Pyrotechnics", ChemPubgCo,NY(1961),281-3 15)W.Gerrard, "The Organic Chemistry of Boron", AcademicPress,NY(1961) 16)D.Lippmann & M.P. Stoltenberg, "Heat Storage Materials", Lithium Corp, NY(June 1961),pp 34-7(Boron) 16b)R.F. Gould,Edit, "Borax to Boranes", Advances in Chemistry Series No 32, American Chemical Society, Washington,DC(1961),240pp 17)US Military Specifications - not found in Dept of Defense "Index of Standards and Specifications, Supplement,Part 1(Aug 1961)

**Boron, Estimation of.** A general procedure has been developed at PicArsn for estimating the boron content of organodecaborane compds. The sample is refluxed in a mixt of perchloric & sulfuric acids with a small amt of K dichromate present

to indicate completeness of digestion. After dilution with water, an aliquot is made alkaline to litmus, then reacidified and refluxed. The pH is adjusted to 7.2 with Ba hydroxide, mannitol is added and the vol of Ba hydroxide soln required to restore the pH to 7.2 is detd. The Ba hydroxide is standardized against boric acid in the presence of the digestion reagent. The method is of general applicability, is relatively rapid and requires no special apparatus or reagents

*Ref*: R.M.Abbott, N.M.Liszt & M.Roth, "Estimation of the Boron Content of Organodecaborane Compounds", Technical Note **No FRL-TN-85**, PicArsn, Dover,NY(1961)

*Note*: It was recommended that this method be included in US Specification **MIL-STD-286**

**Boron Azide.** See Boron Triazide; Vol 1,p A525-L

**Boron Carbide.** See Vol 1,p A71-L

**Boron Compounds.** The compds of boron exhibit, in general, the props of the compds of a non-metal. They indicate that the element is tervalent. The boron hydrides(qv) seem to indicate the possibility of quadrivalency, although this question is not definitely settled(Ref 9)

The Univ of Delaware under Contract DA-36 -034-ORD-2526RD has published a series of reports on "Adducts of Boron Compounds"(Ref 15)

Some of the boron compds listed in the literature are as follows:

*Boron Bromide*. See Boron Tribromide

*Boron Bromide Diiodide*, $BBrI_2$; mw 344.58, col liq, bp 180°(Ref 14,p 376)

*Boron Bromide Pentahydride*, $B_2H_5Br$; mw 106.60, col gas, mp -104°, bp 10°(approx) (Ref 14,p376)

*Boron Carbide*. See Vol 1,p A71-L and Ref 14,p 376. Its use in smoke-producing compns was patented by DeMent(Ref 20,pp 26-7)

*Boron Chloride*. See Boron Trichloride

*Boron Chloride Pentahydride*, $B_2H_5Cl$; mw 62.14, col gas highly unstable, bp -78° at 18mm(Ref 14, p 376)

*Boron Dibromide Iodide*, $BBr_2I$; mw 297.57, col liq, bp 125°, vap d 10.3(Ref 14, p 377)

*Boron Hydrides*. See below, following Boron Fuels

*Boron Nitride*, BN; mw 24.83, hex wh crysts, mp 3000°(subl), d 2.20(Ref 14,378) (See also Refs 3 & 12 and Ref 20a,pp 41-4)

*Boron Oxide*(Boron Trioxide or Boric Oxide) $B_2O_3$; mw 69.64, vitreous col crysts, mp 450° (approx), bp 1500°, d 1.844(Ref 14,p 378) (See also Ref 1, p 39; Ref 18a,p 11; Ref 19 and Ref 20a,pp 30-3). Its use in smoke-producing compns was patented by DeMent(Ref 20,pp 27-8)

*Boron Pentasulfide*, $B_2S_5$; mw 181.97, wh crysts, mp 390°, d 1.85(Ref 14,p 378)

*Boron Phosphide*, BP; mw 41.80, maroon powd, mp 200° (ignites) (Ref 14,p 378)

*Boron Triazide*. See Vol 1,p A525-L

*Boron Tribromide*(Boron Bromide), $BBr_3$; mw 250.57 col fuming liq, fr p -45°, bp 91.7, d 2.650 at 0°; vap press 40mm at 14° and 100mm at 33.5°(Ref 14, p 378-9)

*Boron Triethyl*(Boron Ethyl or Triethyl Borine), $B(C_2H_5)_3$; mw 98.0, col liq, fr p -93°, bp 95°, d 0.6961 at 23°; spontaneously flammable in air or by chem reaction with oxidizers(Ref 14,p 379) (See also Ref 18)

*Boron Trimethyl*(Boron Methyl or Trimethyl Borine) $B(CH_3)_3$; mw 55.9, col gas, fr p -161.5°, bp -20°, d 1.91 g/liter(gas) and 0.625(solid at -100°); highly dangerous when exposed to flame or by chem reaction with oxidizers; spontaneously flammable (Ref 14,p 380)

*Boron Trioxide*, See Boron Oxide

*Boron Triselenide*, $B_2Se_3$; mw 258.52, yel gray powd(Ref 14,p 380)

*Boron Trisulfide*, $B_2S_3$; mw 117.84, wh crysts, mp 310°, d 1.55(Ref 14,p 380)

Böhn(Ref 2) explains that the glowing of the oxide of certain metals(such as $Fe_2O_3$ & $Cr_2O_3$) when heated to dull redness, and the explosive devitrification of certain "glasses" such as $CuB_2O_4$, $Co_2B_2O_5$ & $MnB_4O_7$ on heating to 700 -900°, are caused by the transition from amor to the cryst state(See also Refs 1,4,8,10,11 & 13 for more detailed discussions)

*Refs:* 1)Mellor **5**(1924),23-149 2)J.Böhn,ZAnorg-Chem **149**,217-22(1925) & CA **20**,527(1926) 3)Mellor **8**(1928),108 4)Thorpe **2**(1938),40-6 5)InorgSynth **1**(1939),21-4(prepn of $BF_3$) 6)R.J. Thomas et al,IEC **32**,408-10(1940) & CA **34**,2343 (1940) (Sulfonation & nitration reactions promoted by $BF_3$) 7)G.F.Hennion,USP 2314212(1943) & CA **37**,5077(1943) ($BF_3$ used to promote nitration) 8)Hackh's(1944),139-40 9)Mellor(1946),658-63 10)Kirk & Othmer **2**(1948),588-622 11)Partington (1950),652-59 11a)Groggins(1952),p 32(Effect of $BF_3$ in nitration reactions) (Not found in 5th ed, 1958) 12)F.J.Sowa,USP 2606815(1952) & CA **46**, 11090(1952) (Manuf of BN & metallic nitrides) 13)Gmelin, Syst Nr **13**(1954),123-253 14)Sax (1957),376-80 15)Univ of Delaware "Adducts of Boron Compounds",Quarterly Progress Rpts 2nd through 15th(1 Oct 1957 to 31 March 1961 15a)J.Morel & R.Keck,MP **41**,375-8(1959) (Prepn of

some org B compds contg N) 16)A.V.Topchiev, S.V.Zavgorodnii & Ya,M.Paushkin,"Boron Fluoride and Its Compounds as Catalysts in Organic Chemistry",Pergamon Press,NY(1959) (Translated from Russian by J.T.Greaves) 18)J.T.Maurel et al, MP **41**,375-8(1959)(Organic derivs of boron) 18a)M.Crompton & J.E.Reed,"Some Properties of High Energy Fuel Chemical Materials", Olin Mathieson(1959) 19)J.L.Wilding et al, "The Toxicity of Boron Oxide", Chemical Warfare Laboratories Report, CWLR **2334**(1960) 19a)Kirk & Othmer, 2nd Suppl(1960),109-26 20)J.DeMent,USP 2995526 (1961),pp 26-8 20a)D.Lippmann & M.P.Stoltenberg "Heat Storage Materials",Lithium Corp,NY(June 1961),pp 34-7 for Boron

**Boron Explosives.** The use of amor boron in expls was studied by Phillips(Ref 1) at PicArsn as a component of "Boronite"(qv) expls developed by the Goss Engineering Co of Seattle, Washington. It was concluded, at that time, that replacement of Al by B in military expls showed no advantages over std expls. Boron has been used in the development of some gasless delay fuze compns and in pyrotechnic mixts for flares & incendiary bombs (Ref 3). Werbel(Ref 2a) proposed Ba chromate/boron 95/5 mixt as delay compn & 90/10 mixt as an igniter. Taschler & Jones(Ref 5) have detd the electrostatic sensitivity of barium chromate/boron compns. The performance of boron expls is described by Mader(Ref 4)

The expl compd*Lithium Borazide*, $LiB(N_3)_4$, is described under Boron Azide, Vol 1,p A525-L

Zwicky(Ref 2) of CalTech has reported that by the use of expls contg B, Li, Mg, Al, or Si it is possible to attain energy values of 4-7kcal/cc (common expls & proplnts develop energies not exceeding 3kcal/cc). According to Zwicky it is necessary, however, that the expl reaction generate at least a mod amt of gas to provide energy transfer. This can be accomplished by addg gas generating expl combinations or by incorporating the desirable elements chemically, rather that physically, in the original expl, such as in the reaction:

$$2Al(BH_4)_3 + 6\ O_2(liq) = Al_2O_3 + 3B_2O_3 + 12H_2$$

Projectiles with such expl systems could be useful as artificial meteors since they would be luminous in the high vacuums of interplanetary space (Ref 2) (See also Boron Hydrides, Boronites, Boron Solid Propellants & Borotorpex)

*Refs*: 1)A.J.Phillips,PATR **1292**(1943) 2)F. Zwicky,Experientia **10**,326-8(1954) & CA **48**, 14209(1954) 2a)B.Werbel,PATR **2244**(1955) 3)L.D.Jackson,USP 2796339(1957) & CA **51**, 13399(1957) 4)C.L.Mader,"The Performance of Boron Explosives", Univ of Calif,Los Alamos SciLab,LA-**2341**(1956) (Conf, not used as a source of info) 5)A.F.Taschler & E.E.Jones,PA FRL Tech Notes FRL-TN-3(1960)

**Boron Fuels.** See Boron Hydride Fuels

**Boron Hydrides, Derivatives and Fuels**

**Boron Hydrides**(Boranes). These constitute a group of compds which may be represented by two generic formulas: $B_nH_{n+4}$ and $B_nH_{n+6}$ (Ref 3). The $B_nH_{n+4}$ series is the more stable but all boranes are electron deficient molecules and considerable work has been undertaken to ascertain their structures, their generation from *diborne* & their subsequent interconversions. The existence of some of these compds has been known since 1881. A comprehensive review of boranes may be found in many refs, such as 1,6, 8,9,10,11,12,16,18,19,21,29 & 31

Sax(Ref 27) has discussed the toxicity, fire & expln hazards of boron hydrides. The max allowable concn(MAC) is 0.1p per million in air. These compds are dangerous when exposed to heat or flame or by chem reaction. Boron hydrides evolve hydrogen upon contact with moisture and can propagate a flame rapidly enough to cause expln. The toxicity & health hazards are discussed also by Krackow(Ref 20), Rothberg et al(Ref 37) & Feinsilver et al(Ref 38)

The following boranes are expl, especially if traces of water are present: *Diborane*(Boroethane or Boron Hydride), $B_2H_6$; mw 27.7, col gas having a sickly sweet odor, fr p -165.5°, bp -92.5° (expl on heating to higher temps) d 0.447 (liq at -112°), 0.577(solid at -183°), vap press 224mm at -112°(Ref 27,p 548-9). A classical method for the prepn of diborane was developed by Schlesinger & Brown(Ref 15) and involves the reaction of boron trifluoride etherate with lithium hydride:

$$6LiH + 2BF_3.(C_2H_5)_2O = B_2H_6 + 6LiF + 2(C_2H_5)_2O$$

Other methods of prepn are from Na borohydride by reaction with a Lewis acid (ferric chloride, cupric chloride or boron halides) or by electrolysis of active metal borohydrides, using a suitable electrode system and a suitable solv such as di-(methoxyethyl)ether(Ref 32). Dark elec discharges in a Berthelot ozonizator transform diborane into a nonvolatile yel hydride, $(BH)_x$, which hydrolyzes in water to $H_3BO_3$; with dil $HNO_3$ it forms brn crysts which explode on contact with concd $HNO_3$

(Ref 5). The explosive oxidn of diborane is discussed by Roth & Bauer(Ref 25) (See also Ref 34a p 31-9)

*Tetraborane*(Borobutane), $B_4H_{10}$; mw 53.4, gas having a disagreeable odor, fr p -120°, bp 18° (expl on heating to higher temps); vap press 580mm at 6°; highly dangerous, as shock can shatter the compressed-gas container releasing toxic materials which react vigorously with oxidg agents(Ref 27,p 1160). This and higher boranes result from the pyrolysis of diborane. Although the mechanisms for these reactions are not completely understood, it is known that the unstable tetraborane($B_4H_{10}$) & pentaborane($B_5H_{11}$) are formed along with the stable pentaborane($B_5H_9$)(Ref 35) (See also Ref 34a,p 111)

*Pentaborane, Stable*(Pentaborane Enneahydride), $B_5H_9$; mw 63.2, col gas or liq, fr p -46.6°, bp 0° at 66mm; explodes spontaneously in air; d 0.61 at 0°, vap press 66mm at 0°, vap d 2.2(Ref 27,p 983-4) (See also Ref 34a,pp 81-90 and Refs 38a & 39)

*Pentaborane, Unstable*(Dihydropentaborane), $B_5H_{11}$; mw 65.2, col liq which turns yel on standing, fr p -129°, bp 0° at 57mm; explodes spontaneously in air(Ref 27,p 984)(See also Ref 34a,p 91)

*Hexaborane*(Boron Hydride or Hexaboro Decahydride), $B_6H_{10}$; mw 75.0, col liq which turns yel on standing, fr p -65.1, bp 0° at 7mm (explodes on heating); d 0.69 at 0°, vap press 7.2mm at 0°, vap d 2.6(Ref 27,p 750)

*Decaborane*(Boron Hydride or Decaboron Tetradecahydride), $B_{10}H_{14}$; mw 122.3, col ndls, mp 99.7°, bp 213°(explodes on heating in 0 at 100° and in air when heated to decompn), d 0.94(solid) & 0.78(liq at 100°), vap press 19mm at 100°(Ref 27,p 534). The heat capacity, heats of fusion & vaporization, vap press and entropy are reported by Furukawa & Park(Ref 24) (See also Ref 34a, pp 25-30)

*Boron Hydride Derivatives*. Alkyl boranes can be prepd by alkylation of key intermediates, of diborane or of higher boranes. Alkylation of a borane will proceed more readily if a functional group, such as a halogen or an active metal atom, is attached to the borane. For example, a haloborane may react with a metal alkyl to produce an alkyl borane, or a metal polyhydropolyborate may react with an alkyl halide to produce an alkyl borane(Ref 35). Boranes may be alkylated or arylated with an unsaturated hydrocarbon(Ref 13). Alkoxy derivs of boranes can be prepd by allowing a borane to react with an appropriate alcohol(Ref 4). In addn to these methods the Grignard reaction can be employed. For example, decaborane will react with a methyl Grignard and produce the product expected or it will react with double Grignard reagents to produce a cyclic deriv(Ref 28). Metalloboranes can be prepd from metal amalgams, as illustrated by the following reactions (Ref 3):

$$B_2H_6 + NaHg_x \longrightarrow Na_2B_2H_6 + Hg$$

$$B_4H_{10} + NaHg_x \dashrightarrow Na_2B_4H_{10} + Hg$$

*Aluminum Borohydride*, $AlB_3H_{12}$; mw 71.53, liq, fr p -64.5°, bp 44.5°, vap d 400mm; ignites spontaneously in air(Ref 27,p 260). Brokaw et al(Ref 14) reported that the oxidn of 1-butene induced by aluminum borohydride was expl after an induction period. Reaction with 1,3-butadiene yielded immed expln but normal butane($n\text{-}C_4H_{10}$) gave no expln. See also Ref 34a,pp 2-5 and pp 66-7(Lithium Borohydride) & pp 101-7(Sodium Borohydride)

The structures of some ethylated derivs of *pentaborane* and *decaborane* are reported by Williams(Ref 34). Stock & Pohland(Ref 2) reported the formation of complexes by the reaction of $NH_3$ with boranes. The structure & props of these boron hydride ammoniates were studied by Agronomov(Ref 7)

In addn to their uses as high energy fuels(HEF), boron hydrides and their org derivs are useful as diesel oil additives, as polymerization catalysts and as cetane improvers presumably because they increase the flame speed of fuel-air mixts. Many other possible applications are suggested for the metalloboranes and their derivs(Ref 36)

*Refs*: See under Boron Hydride Fuels

**Boron Hydride Fuels**(Boranes). Since WWII many articles on the chemistry and uses of boron & its compds as additives to fuels(gasoline), and of the use of alkyl boranes, as the so-called "exotic" or high-energy fuels(HEF), have appeared in tech and nontechnical journals & newspapers. In automobile fuels(gasoline) boron compds, such as alkyldihydroxyboranes, are added in relatively small amts (Ref 22). In HEF for air-breathing jet & rocket engines, alkyl borane is the fuel itself and is not an additive. Both jet and rocket engines have fuel requirements which are not the same as those for the internal combustion engine. Martin(Ref 35) has summarized these requirements as follows: a)high heat of combustion b)low vap press c)thermal stability d)high density e)high flame speed and f)physical props which insure its safe handling during manuf, shipping & storage

According to Martin(Ref 35), the US Dept of Defense in 1952 made the chem industry aware of

its need for better HEF. No limitations were placed with regard to which atoms, molecules or mixts thereof might be used to synthesize an improved HEF. At that time there were available the following fuels:

| Fuel | BTU/lb |
|---|---|
| Liquid hydrogen | 52470 |
| Pentaborane($B_5H_9$) | 29961 |
| JP-4(kerosene hydrocarbon) | 18605 |

Liq hydrogen represents the ultimate attainable in a fuel. However, its low density & low bp make its use on a large scale difficult. Study of the periodic table of the elements indicated that a better HEF could be prepd only if hydrogen, beryllium or boron were used as "building blocks". Beryllium was eliminated, according to Martin(Ref 35), because of its limited availability, extreme toxicity of its compds and because no liq complexes of Be are known. Consequently boron & its hydrides were selected as the materials from which the synthesis of a better HEF would be attempted

Boehm(Ref 27a) reported that scientists at the Lewis Flight Propulsion Labs of NACA began in 1946 to investigate some of the boranes synthesized by GE & Aerojet-General Corp, Azuza, Calif. Soon thereafter the ONR became interested in boranes and awarded contracts to several laboratories which focused their attn on three basic compds: *diborane* ($B_2H_6$), a gas having $Q_c$ 32000; *pentaborane* ($B_5H_9$), a liq having $Q_c$ 30000; and *decaborane* ($B_{10}H_{14}$), a solid having $Q_c$ 28000 BTU/lb at STP

These were the three most common boranes known at that time. Because the $Q_c$ of each is high, it was predicted that these boranes might be modified to convert them to liq compds, having the desired props, and without losing much of their energy content. The ideal HEF molecule would contain therefore boron, as much hydrogen as possible & a third element. After eliminating beryllium because of its scarcity & toxicity the next best elements, from the viewpoint of their $Q_c$ values, are lithium and carbon. Because hydrocarbons are fuels, it was decided to modify boranes by introducing a small quantity of C into them. From a study of the boron-hydrogen-carbon ternary system, areas were described representing compns or empirical formulas for the desired molecules(Ref 35). The syntheses of these molecules is classified and the processes used cannot be described. For example, see Ref 33

High-energy fuels under the trade names of "HEF" (Olin Mathieson Chem Corp) and "Hi-Cal"(Callery Chem Co) have been produced in plants owned by these companies and in plants operated under contract for the US Dept of Defense. The Callery Chem Co has a company-owned plant at Lawrence, Kansas and a plant operated for the Dept of Navy at Muskogee, Oklahoma. The Olin Mathieson Chem Corp has a company-owned plant, a plant operated for the Dept of Navy, and a plant operated for the Dept of Air Force, all located at Niagra Falls,NY (Ref 35)

Martin(Ref 35) has compared the pertinent props of a typical HEF with those of JP-6(a special grade of kerosene for jet aircraft which are as follows:

| Properties | JP-6 | HEF |
|---|---|---|
| Heating value, BTU/lb | 18600 | 25000 |
| Specific gravity at 70°F | 0.78 | 0.82 |
| Flame speed | x | 6-10x |
| Chemically stable at °F | 500 | 500 |

These data indicate that borane fuels have many props which are superior to those of JP-6. Comparison of the performance of a borane fuel with that of JP type, and using liq O as oxidizer, shows that a HEF increases the range of air-breathing engines or rockets by ca 50% over that obtd with a JP fuel in the same vehicle

Boranes as fuels compare favorably with other well established fuels in liq propellants(Ref 35) as shown in the following table:

| Liq Propellant | Wt % Free $H_2$ | Specific Impulse sec (20 atm) |
|---|---|---|
| $N_2H_4$-$F_2$ | 0 | 279 |
| $N_2H_4$-$F_2$-$H_2$ | 10 | 323 |
| $O_2$-$H_2$ | 16 | 354 |
| $F_2$-$H_2$ | 8 | 361 |
| $B_2H_6$-$O_2$-$H_2$ | 12 | 363 |
| $B_5H_9$-$O_2$-$H_2$ | 14 | 363 |

This table also indicates the advantage of using hydrogen as a fuel in liquid proplnts. When only 10% H is added to a hydrazine-fluorine system, the thrust(specific impulse) is increased approx 15%. Without hydrazine, the hydrogen-fluorine system gives a further increase of approx 12%. Proplnts contg boranes have higher specific impulse values than are available from well-known energetic systems, such as $O_2$-$H_2$ & $F_2$-$H_2$ systems (See also discussion by Clark Ref 17)

A review of modern proplnts for jet engines, particularly the *aluminum borohydride* ($AlB_3H_{12}$), has been made by Orengo(Ref 23). See also the dis-

cussion by Sutton(Ref 26) and by Warren(Ref 30) *Refs*: 1)Mellor **5**(1924),33-9 2)A.Stock & E.Pohland,Ber **59B**,2210-23(1926) & CA **21**,541(1927) 3)A.Stock, "Hydrides of Boron and Silicones", Cornell Univ Press,Ithaca,NY(1933) 4)A.B.Burg & H.I.Schlesinger,JACS **55**,4020(1933) 5)A.Stock & W.Mathing,Ber **69B**,1456-75(1936) & CA **30**,7056-7(1936) 6)Thorpe **2**,(1938),40-3 7)L.E.Agronomov, ZhObshchKhim **10**,1120-40(1940) & CA **35**,1333-35 (1941) 8)H.I.Schlesinger & A.B.Burg,ChemRevs **31**,1-41(1941) 9)S.H.Bauer,ChemRevs **31**,43-75 19)Kirk & Othmer **2**(1948),593-600 11)H.J.Emeléus, AnalesRealSoc EspañFis y Quím **Ser B44**,675-88 (1948) 12)R.P.Bell & H.J.Emeléus,QuartRev **2**, 132-51(1948) 13)T.D.Hurd,JACS **70**,2053(1948) 14)R.S.Brokaw et al,JACS **72**,1793-5(1950) & CA **44**,5686-7(1950) 15)H.I.Schlesinger & H.C.Brown, USP 2543511(1951) 16)H.C.Brown,C&EN **29**,5231-3(1951) & CA **46**,3437(1952) (A discussion of H.I. Schlesinger's researches on borohydrides) 17)J.D. Clark,Ordn **36**,661-3(1952) & CA **48**,11062(1952) (Rocket proplnt fuels such as $B_2H_6$, $NH_3$ & $N_2H_4$ and oxidizers such as $O_2$, $H_2O_2$ & $HNO_3$ are discussed) 18)H.I.Schlesinger et al, JACS **75**,186 (1953) & CA **47**,3741-2(1953) 19)Ya.M.Paushkin, UspekhiKhim **22**,1114-37(1953) & CA **48**,487(1954) 20)E.Krackow,ArchIndHygOccupationalMed **8**,335-9(1953) & CA **48**,13947(1954) 21)Gmelin Syst Nr **13**(1954),97-123 22)S.M.Darling,USP 2710251 & 2(1955) 23)F.Orengo,Chimica(Milan) **11**,55-7 (1955) & CA **49**,16383(1955) (A review of modern proplnts for jet engines, particularly the borohydrides, such as $AlB_3H_{12}$) 24)G.T.Furukawa & R.P.Park,JRNBS **55**,255-60(1955) (Research Paper No **2627**) & CA **50**,11796(1956) 25)W.Roth & W.H. Bauer, "Combustion of Diborane-Oxygen Mixtures at the Second Explosion Limit", 5th Symposium on Combustion,Reinhold,NY(1955),pp 710-17;JPhChem **60**,639-41(1956) & CA **50**,13639(1956) 26)Sutton (1956),170 27)Sax(1957),377-8 27a)G.A.W.Boehm Fortune(Dec 1957),166 27b)Kirk & Othmer,First Suppl(1957),103-30(155 refs)(Boron hydrides) 28)B.Siegel et al,JACS **80**,4523(1958) 29)W.N. Lipscomb, "Recent Studies of the Boron Hydrides", Univ of Minnesota(1958) (Contract DA-11-022-ORD-1554) 30)Warren(1958),22-4 31)J.Cueilleron, Chim&Ind(Paris) **80**,553-60(1958); reviewed in Explosivst **7**,152(1959) 32)R.M.Adams, "The Preparation of Diborane",Paper No **29**; "From Borax to Boranes", Symposium, 133rd ACS Meeting, San Francisco(1958) 33)L.I.Braddock, "Preparation of Boron Fuel Components", Callery Chem Co (1958) (Conf, not used as a source of info) 34)R. L.Williams,ERDE Rpt No 12/R/59(1959) (Conf, not used as a source of info) 34a)M.H.Crompton & J.E.Reed,"Some Properties of High Energy Fuel Chemical Materials",Olin Mathieson(1959) 35)D.R. Martin,"The Development of Borane Fuels",JChem Educ **36**,208-14(1959) 36)Callery Chem Co,"Product Information Digest", C&EN **37**(May 1959) 37)S.Rothberg et al,"Toxicity and Personal Decontamination of Boron Hydride Propellant Fuels", ChemWarfare Labs,CWLR **2355**(1960) 37a)C.S.H Herrick et al,IEC **52**, 105-12(1960) (Borane Pilot Plants) 38)L.Feinsilver et al,"The Acute Inhalation Toxicity of Several Boron Hydride Fuels," Chem Warfare Labs Rpt CWLR **2367**(1960) (Conf, not used as a source of info) 38a)NAAI,Rocketdyne Div,"Pentaborane Handling Manual", **R-3137** (1961) 39)Callery Chem Co,"Physical Properties of Liquid Pentaboranes"(1961) 40)Anon,"The Handling and Storage of Liquid Propellants", Office of the Director of Defense Research and Engineering", Washington,DC(1961),178-88(Alkyl borane fuels) 41)R.F.Gould,Edit,"Borax to Boranes", Advances in Chemistry Series No 32,American Chemical Society, Washington,DC(1961),240pp

**Boronites.** The Goss Engineering Co of Seattle, Washington developed several expls called "Boronite A", Boronite B" & Boronite C". These were prepd by adding so-called amor boron to Amatol to make expls possibly suitable for military applications

The compositions of the Boronites studied at PicArsn are as follows(Ref 2):

| Composition | Boronite A | Boronite B | Boronite C |
|---|---|---|---|
| TNT | 10 | 20 | 36 |
| AN(Ammonium Nitrate) | 83 | 75 | 62 |
| Boron(amor) | 7 | 5 | 2 |

Tests of these expls,in comparison with TNT, 80/20 Amatol, Ammonal & Torpex,showed them to have approx the same sensitivity to impact as Ammonal, but more sens than either 80/20 Amatol or TNT,and less sens than Torpex. The brisance values were less than those of Ammonal, Torpex, TNT & 80/20 Amatol, except for Boronite C, which gave a higher value than 80/20 Amatol. Fragmentation tests also showed the Boronites to be inferior to TNT with regard to the number of fragments produced. However, Ballistic Mortar Test showed all Boronites to be ca 20% stronger than TNT, but inferior to Ammonal & Torpex

Doubt arose as to the purity of this "brown boron"

since, from a theoretical viewpoint, the substitution of boron for Al should result in the development of much higher temps in the propulsive gases. An approx analysis of the brown boron was given by Goss Engineering Co as follows: $AlB_{12}$ 11, $B_7O$ 50, $B_4H_3$ 12, $Al_2O_3$ 25, $Fe_2O_3$ 0.5 & $SiO_2$ 1.5%. It is apparent that this material was not amor boron but a very impure oxide

It was concluded that the "boron product" used above was of no value for use in AN/TNT expls because of its deleterious effects on the stability and brisance values of such mixts. Also, it was concluded that the Boronite expls "A", "B" & "C" offered no advantages over TNT or other std expls now being used (Ref 2)

Thorpe(Ref 1) defines boronite as a sulfide of Cu & Fe, and of importance as an ore of Cu(Cu 45-71%). The exact compn of the mineral, boronite, has long been doubtful($Cu_5FeS_4$)

*Refs*: 1)Thorpe **2**(1938),32 2)A.J.Phillips,"The Use of Amorphous Boron in Explosives", PATR **1292**(1943)

**Boron Oxide.** See under Boron Compounds

**Boron Solid Propellants.** The investigation and use of boron in solid proplnts are described in the following classified repts

*Refs*: 1)Rohm & Haas Co Rpt **P-55-1S**(Aug 1955) (Conf) 2)Reaction Motors Inc Rpts **074-Q1** & **074-Q2**(1956) (Conf) 3)E.Delaney & P.Lensi, Reaction Motors Inc 4th Quarterly Rpt(June 1957) (Conf) 4)E.Delaney & P.Lensi,Thiokol Chem Corp, Reaction Motors Div Rpt **RMD-074F** (1958 -59) (Final Rpt on Contract NOrd 16895) (Conf) 5)D.J.Mann,Thiokol Chem Corp,Reaction Motors Div Rpt **AERL-05539** (1959) (Conf)

**Boron Triazide.** See Vol 1,p A525-L

**Boron Trioxide.** See under Boron Compounds

**Borotorpex.** A castable HE mixt composed of RDX, TNT & boron in various proportions. One compn of RDX/TNT/boron-46/44/10 has the following props: d 1.742, *brisance* by Plate Denting Test 127% TNT, *detonation velocity* 7600 m/sec at d 1.74 and *power* by Ballistic Mortar Test 129% TNT (Ref 3). Other formulations of Borotorpex and their *power* by Ballistic Mortar Tests are as follows(Ref 2,p 16): 48.6/46.4/5.0 127%, 47.1/44.9/8.0 131%, 43.5/41.5/15.0 112% and 41/39/20 101% TNT

*Refs*: 1)D.P.MacDougall & E.H.Eyster,"Preparation and Testing of Explosives", NDRC Div 8 Interim Rpt **PT-34**(1945),p 22 2)L.C.Smith & E.H.Eyster, "Physical Testing of Explosives,Part III Miscellaneous Sensitivity Tests; Performance Tests", OSRD Rpt **5746**(1945),pp 14,16 & 21 3)Anon, "Summary Technical Report of Division 8, NDRC", Vol 1,Washington,DC(1946),pp 39 & 45

**Boroxazolidines**(Boroxazo Compounds). A study of the structures & reactivity of a series of boroxazolidines, such as B,B-diphenylboroxazolidine, $H_2C-CH_2-O$ / $H_2N\longrightarrow B(C_6H_5)_2$, has been reported by Weidmann & Zimmerman(Refs 1 & 2). The expl props of these boroxazo compds were not detd

*Refs*: 1)H.Weidmann & H.K.Zimmerman,Jr,Ann **619**,28-35(1958) & **620**,4-7(1959) 2)H.K.Zimmerman Jr & H.Weidmann et al, Texas A&M Res Foundation Status Rept Nos **1**(1959), **2**(1959), **3**(1960), **4**(1960), **5**(1960), **6**(1960), **7**(1961) & **8**(1961)(OOR Proj No **2359**, Contract DA-23-072-ORD-1432)

**Bosch, Carl**(1874-1940). Ger scientist who specialized in the prepn of nitrogen-contg org compds and collaborated with Haber in the synthesis of ammonia. Was director of IGFarbenindustries

*Refs*: 1)C.Krauch,AngChem **53**,285-8(1940) 2)P. Müller,SS **35**,123-4(1940)

**Bostaph's Explosive.** Contained $KClO_4$ 37, DNB 11, $NaNO_3$ 43, woodmeal 8 & rosin 1%

*Ref*: H.P.Bostaph,USP 1038275(1912) & CA **6**,3524 (1912)

**Bottelage des Poudres**(Fr) (Trussing or Bundling of Propellants). In order to facilitate loading operations with proplnt chges for some guns and to have chges with higher d than loose proplnt, the following method was developed in France:

A weighed quantity of loose strands of proplnt was prepd at the proplnt plant in a bundle(*fagot* in Fr). This was compressed by means of a special hydraulic press, called "botteleuse hydraulique", and tied by means of silk threads. The compressed bundles were loaded in waterproof containers and shipped in this condition to the place of ammo loading. As the wt of each bundle was known, the gun chge could be prepd in the field without weighing, thus saving time

*Refs*: 1)Venin,Burlot & Lécorché(1932),599 2)Pepin Lehalleur(1935),305

**Böttger,Rudolph(or Böttcher,R)** (1806-1887). Ger professor at the Univ of Frankfort-am-Main; dis-

covered guncotton independently of Schönbein, but later in the same year(1846). He also invented matches and contributed to the study of poisoning of Pt calatysts
*Note*: The name is spelled Böttcher by Colver(Ref 2) & Stettbacher(Ref 3) and Böttger by Marshall (Ref 1) & Davis(Ref 4)
*Refs*: 1)Marshall 1(1917),39 2)Colver(1918),2 3)Stettbacher(1933),12 4)Davis(1943),249

**Bottles.** Military slang for JATO. Also shop or trade language for containers of high-pressure air or other gas used for auxiliary power in complete missile power plant
*Ref*: Rocket Encycl(1959),58

**Bouche**(Fr). Muzzle(Art)

**Bouche à feu**(Fr). Gun; piece of artillery

**Bouchon**(Fr). Fuze seat of projectile; tompion; fuze-plug

**Bouchon détonant**(Fr). Primer plug(fuze)

**Boudineuse**(Fr). An app for cartridging gelatin dynamites

**Boulengé(Le),Chronograph.** Employed in early methods for measuring the vel of deton of expls. A very long cylindrical column of expl was initiated at one end and the time for the explosion to travel to the other end was recorded by Le Boulangé Chronograph. It is still used to measure the muzzle vel of projectiles. This apparatus has been replaced by the Mettagang Recorder, Method of Dautriche and the Optical & Electronic Chronographs for measuring velocities of deton of expls (See also Chronographs)
*Refs*: 1)Brunswig,Props(1926),422 2)Sukharevskii & Pershakov(1932),211 3)Stettbacher(1933),55 4)Pepin Lehalleur(1935),101 5)Hayes(1938),85-7 6)Meyer(1943),32 7)Pérez Ara(1945),93

**"Bouncing Betty" Flare** (Trip Flare M48). A device constructed like Bouncing Betty Mine(see below), except that the fragmentation proj is replaced by a flare which is projected upwards when a firing device is activated by a slight pressure or pull. The device is hidden under-ground or comouflaged, and is intended to give warning of enemy marauders or infiltration by hostile troops
*Ref*: Ohart(1946),308

**"Bouncing Betty" Mine.** An antipersonnel mine of the fragmentation type which is activated by small pressure(such as a man walking over the buried device) causing an igniter to fire and initiate a propellent chge. The proplnt shoots the fragmentation projectile from the ground and at the same time activates a time fuze. When the proj reaches a height several ft above the ground, the HE chge detonates and sprays steel fragments in all directions
*Refs*: 1)Ohart(1946),363 & 367 2)Cook(1958), 18-21

**"Boundary" Diameter** Precise detn of the velocities of deton in cylinders of cast TNT(Buxton rotating -mirror camera) shows that the vel rises as the diam is increased from a "boundary diam", below which there is no propagation, to a "limiting diam" at which the deton vel reaches a max. The effect of heavy confinement is to reduce the boundary and limiting diams; the max vel remains unaltered
*Ref*: W.B.Cybulski et al,PrRoySoc **197A**, 51-72 (1949) & CA **44**,1707-8(1950)

**Bourrage**(Fr). Tamping or stemming

**Bourrelet**(Fr). Rim(of a cartridge) or centering band of a projectile. An accurately machined surface(of diam sl larger than the shell body) which rests on the lands of the bore. Its function is to center the projectile in the bore and to guide it during its travel through the bore. Generally, the bourrelet is located at the forward end of the shell body, but some large caliber projectile have front & rear bourrelets. The diffr between the diam of the bourrelet and that of the bore of the weapon is known as the *clearance*. This value varies in a new gun from 0.005" for small calibers to 0.02" for large calibers
*Refs*: 1)Anon, "Ammunition Inspection Guide", TM **9-1904**(1944),11 2)Ohart(1946),98 & 118 3)Anon, "Artillery Ammunition", TM **9-1901**(1950), 35 4)Anon, "Ammunition General", TM **9-1900** (1956) 125

**Bow and Arrow.** See under Arrow, Vol 1,p A488-R and Arbalest or Crossbow, Vol 1,p A477-L
*Addnl Ref*: W.L.Rogers, ArOrdn **15**,334-40(1935) (The bow as a missile weapon)

**Bowden,F.P. and Yoffe,A.D.** Authors of "Initiation and Growth of Explosives in Liquids and Solids", Cambridge Univ Press(1952),104pp

**Bowen** patented in 1883 the use of carbonized and pulverized lignite in lieu of charcoal in gunpowders intended for use in cannon. The same inventor patented in 1886 the use of charcoal obtained by carbonization of corn or other cereals
*Ref*: Daniel(1902),80

**Box Ovens.** Cubbage & Simmons(Ref) have made studies of industrial type box ovens and presented design data for top expln reliefs (the lowering of excess pressure by venting). The pressure-time variation in an oven during an expln was found to consists of two pressure peaks. Based on measurements of the pressure developed by explns of manufd gas-air mixts in drying ovens, empirical formulas were derived relating the oven vol, venting area & wt of relief to the pressure developed by the most violent gas-air mixt. Pressure measurements were made also for several gases & vapors other than manufd gas, but Cubbage & Simmons(Ref) recommend that the design of oven reliefs be based on the pressures developed by manufd gas
*Ref*: P.A.Cubbage & W.A.Simmons,Gas Council, Research Commun **GC23**,46pp(1955) & CA **50**, 2948(1956)

**Boyd Powders.** Between 1893 & 1896 Boyd of Birmingham, England, patented several expl compns:
*Blasting expls* for use in mines: a)$KNO_3$ 43.75, sulfur 18.75, Fe or Ca oxide 12.50, $Ba(NO_3)_2$ 12.50, PA 6.25 & wood meal or wood dust 6.25%. This powd can be ignited by a miner's fuse in a manner similar to BkPdr; b)$NaNO_3$ 39.95, sulfur 22.20, AmmP 11.10, $(NH_4)_2Cr_2O_7$ 10.10, $K_2Cr_2O_7$ 5.55, turf dust 5.55 & $Ca(OH)_2$ 5.55%. The ingredients were mixed with cotton oil and pressed into cartridges
*Propellant-Fumelessite* (smokeless)- contd the same ingredients as blasting expl (a) but in different proportions
*Ripplene* - an improved compn contg the same ingredients as blasting expl (a) except up to 10% PA was added
*Ref*: Daniel(1902),81-2

**Boy's Apparatus.** A device for taking shadow photographs of projectiles in flight
*Ref*: Cranz, vol **3**(1927),264

**B Powder.** See B(Poudre), this volume

**BP (Pulver) (Called in Fr Plastoménite).** An early Ger proplnt, invented by Güttler in 1889, consisting of NC, nitrated derivs of sugar, gum or starch with one of the nitrated aromatic hydrocarbons, such as benzene, toluene, phenol or naphthalene. The prod could be used alone or in admixt with nitrates, chlorates, picrates or chromates

In England the Plastoménite mixt, consisting of NC, DNT & $Ba(NO_3)_2$, was considered a smokeless powd. Three types were manufd: JCP, BP & KMP for sporting powds, carbines & military weapons, respectively

The mixt of NC with 5 times its wt of DNT was prepd in the form of brn grains. It was used in Germany for hunting purposes. The expl mixt of Güttler was considered remarkably heat resistant and in official experiments at Bucharest, in 1893, gave excellent results

Güttler, in 1897, proposed a modification of the compn by the addn of 0.5-10.0% resin(colophony or rosin). The mass was granulated and obtd as granules varying in color from lt brn to dk brn
*Ref*: Daniel(1902),82 & 634

**BPY.** A cast double-base proplnt for gas generators developed at ABL. Its compn & props are given in conf Propellant Manual SP1A/M2(1959), Unit No579

**BR 152(Polvere)** (Ital). A brn prismatic powd used in Ital 149 & 152mm cannons
*Ref*: Daniel(1902), 82

**Br 431(Polvere)** (Ital). A brn prismatic powd employed in 254, 343 & 431mm cannons by the Ital navy
*Ref*: Daniel(1902),82

**Bracket's Sporting Powder.** A smokeless powd, formerly manufd in the USA, consisted of nitrolignin(sol) 31.43, nitrolignin(insol) 13.70, $NaNO_3$ 19.76, humus 18.94, charred wood flour 13.22 & moisture 2.95%
*Ref*: Daniel(1902),82

**Braconnot,H.** Fr scientist who was the first to prep, in 1833, *nitrostarch*(NS) which he called "xyloidine". This was done by dissolving starch in strong $HNO_3$ and pouring the viscous liq into w. Braconnot also nitrated sawdust, cotton & linen to products which he considered to be identical with the xyloidine from starch. These products contained only 5-6% N and were not suitable for military purposes. The name xyloidine is now applied generally to any prod made by dissolving a carbohydrate in $HNO_3$ and pouring into w. In spite of

the cheapness of starch as a raw material, it has never replaced cotton; this is due to the relative instability of NS and to the mechanical difficulties in nitrating and purifying it
*Refs*: 1)Daniel(1902),82 & 453 2)Marshall 1(1917) 194 3)T.Urbański,MAF **13**, 825-6(1934) 4)Davis (1943),245

**Brain Powders.** Mixts, patented in England in 1873, contg NG 40-78% with $KClO_3$, $KNO_3$, sugar, cork charcoal, wood meal, dextrin,etc added
*Ref*: Daniel(1902),83

**Brakes**(Weapons). Almost all towed artillery and self-propelled weapons have parking and stopping brakes; the light and smaller carriages have only parking brakes. Stopping brakes are operated from the prime mover to slow down or stop the carriage as the prime mover slows down or stops. Parking brakes are operated by hand-brake levers on the carriage and are used for parking the weapon when coupled to or detached from the prime mover
*Ref*: Anon,"Fundamentals of Artillery Weapons", TM **9-2305**(1947),126

**Brakes, Muzzle** Short cylindrical extensions for the muzzle of a cannon, having a number of baffles on the inside, against which the gases, following the projectile from the tube, strike. The gases exert a forward force on the baffles that partially counteracts the rearward force of recoil and thereby reduces the force of recoil
*Refs*: 1)O.W.Strickland et al,"General Summary of Explosive Plants", PB Rpt No **925**)1945),83 2)TM **9-2305**(1947),10 & 54

**Brakes, Recoil.** Mechanisms which control the recoil of weapons. The modern recoil brake is a hydraulic brake and consists of a piston which moves in a cylinder filled with oil. The recoil brake is attached to the weapon in either of two ways: a) the cylinder is attached to the tube(gun barrel) and moves with it during recoil and counter-recoil, while the piston is fixed to the *carriage* b) the piston is attached to the tube and moves with it during recoil and counter recoil, while the cylinder is fixed to the carriage. In either case, when the tube recoils, there is relative motion betw the piston and the cylinder and the operation in both cases is fundamentally the same
*Ref*: TM**9-2305**(1947),42

**Brame's Stability Test.** A 2-g sample of NC, previously dried at 40°, is closely packed into a decompn tube(two similar tubes are used in each test) which is placed in a bath heated at constant temp by boiling vapors(for a temp of 110° toluene; for 115° toluene 3ps & xylene lp; for 130° amyl alc). The tube is first evacuated and then sealed off while under vacuum by means of a stop-cock. The evacuated tube is heated for 6 hrs at the desired test temp. At the end of this time the stop-cock arrangement on the tube is connected to a manometer which, upon opening the stop-cock, registers the press created by the gases evolved from the decompn of NC during heating. The amt of gas, as ml of NO, is calcd from the manometric reading

For example, 2g of 13%N NC evolved ca 1.4ml of gas when heated at 115° and 4.5ml at 130°; 2g of 12%N NC when heated at 130° evolved ca 5.8ml as measured under STP
*Ref*: J.S.S.Brame,JSCI **31**,159-61(1912)

**Bram's Powder.** A mixt of K nitrate, K chlorate, charcoal & oak sawdust 60, saturated with NG 40%
*Ref*: CondChemDict(1942), 288(not found in later editions)

**Bran**(called Kleie in Ger & Son in Fr). The husks or outer skin covering of grains of wheat, rye etc which are separated from the ground grain (flour or meal) by sifting or bolting. The separation of bran & starch from corn is described by Kawabe (Ref 3). Wheat bran contains starch 52, gluten 14.9, fat 3.6, sugar 1, wood fiber 9.7, salts 5 & water 13.8%. Its nitration with mixed nitric-sulfuric acids produces an expl, resembling NC in its props. The nitrated bran has been used in some dynamites: NG 30 to 60 & nitrated bran 70 to 30). See Forcite
*Refs*: 1)Gody(1907),471 2)Kast-Metz(1944),336 3)T.Kawabe,JapP 3174(1953) & CA **48**,8570(1954)

**Brandeisl Powder.** A mixt of $KNO_3$ 16, sulfur 2 & sugar 3ps
*Ref*: Daniel(1902),83

**Brander,** an obsolete name for a solid-propInt rocket engine which was manufd by F.W.Sander at Wassermünde, Germany
*Ref*: Rocket Encycl(1959),59

**Brandt Mortars.** Light-weight mortars designed, beginning in 1918, by the Edgar Brandt Co of Paris. The first mortar was of 45-mm caliber and was capable of throwing an appreciable chge to

a range of 150 to 1100yds. The mortar consisted of a smooth-bore barrel, closed at one end and fitted with an interior firing pin, against which the projectile fell and was automatically fired, as in the Stokes mortar. To the base of the mortar there was attached a small circular plate which rested upon the ground and was held in place by a spike protruding from the center. Projectiles were made of steel and provided with four vanes. Total length of the mortar was 28", approx wt 8.8lbs; wt of projectile w/fuze 1.2lbs, wt of HE chge 0.2lb; max propelling chge 62g & rate of fire 30-40 rounds/min

A larger mortar was of 60mm caliber, total length 40", approx wt 19.8lbs; wt of loaded projectile 2.8lbs, wt of HE chge 0.4lb, wt of propelling chge 230g; range 150-1350yds, rate of fire 30-35 rounds/min. This mortar was similar in construction to the 45-mm mortar except that it was provided with 4 legs to hold it in position

*Refs*: 1)ArmyOrdHdb, "History of Trench Warfare Matériel", Govt PrintingOfc, Washington,DC(1920), 129-30 2)M.E.Melroy, "Examination of 47mm and 60mm Brandt Mortar Ammunition",PATR **892**(1938) 3)V.R.Reed, "Examination of 60mm Brandt Mortar Ammunition(Second Lot) HE & Practice Rounds ", PATR **967**(1939) 4)A.B.Schilling, "Examination of Two Unfired 120mm HE Shell Complete Rounds of Brandt Mortar Ammunition(French)",PATR **1823**(1951) (Conf)

**Brandt Projectiles.** These are described in the following refs:

*Refs*: 1)C.G.Scheibner, "Investigation of 25mm Brandt Armor Piercing Projectile", PATR **900** (1938) 2)A.B.Schilling, "37mm Armor Piercing Projectile(Brandt)",PATR **1003**(1940) 3)A.B. Schilling, "Examination of Three Unfired 100mm Fixed Rounds of French Gun Ammunition Comprising One AP-T Round, One APC-T Round and One TP-T Round", PATR **1912**(1953)(Conf)

**Brank's Powders.** Von Brank patented in 1890 a smokeless powd contg NC & wax, such as carnauba. The same inventor patented in 1891-2 the following compns:

*Blasting expl:* $KClO_3$ 87 & resin 13%; *Sporting powd* $KClO_3$ 70.5, boiled linseed oil 28.5 & PbO 1.0%; and *Military rifle powd* $KClO_3$ 59.9, $K_2Cr_2O_7$ 34.5 & carnauba wax 6.0%

*Refs:* 1)Daniel(1902),790 2)Perez Ara(1945,213

**Brass.** A copper-base alloy contg an appreciable amt of Zn. Formerly, brass was an alloy of copper & tin. Various copper-base alloys are described in Hackh's (Ref 1) & in US specs(Ref 3). Brass usually is yel in color, is harder and stronger than copper, and is malleable & ductile. Its props vary with its compn

A 70/30-Cu/Zn brass is used to make the *cartridge cases* which contain the propelling chges for fixed and semi-fixed artillery ammo

*Refs*: 1)Hackh's(1944),142 2)Merriam-Webster's (1951),327 3)USSpecifications: JAN-B-67(1) (Brass, cartridge,disks); MIL-B-50B(Brass, cartridge: sheet,strip,plate,bar and disks); MIL-B--15894A(Brass; die castings); MIL-B-13351(Brass forgings, free machining); MIL-B-5697A(2)(Brass laminated); MIL-B-13492(Brass, leaded; tubing, seamless); MIL-B-994A(Brass,naval,wrought); MIL-B-11552(Brass powder for sintered parts) and MIL-B-12128A(1)(Brass, sintered; structural parts)

**Brassage des poudres**(Fr). Mixing or blending of propInts. In order to obtain propInts having uniform ballistic props, they must be blended thoroughly. Roche describes the method of mixing powders as used by la Poudrerie de Bergerac

*Ref*: M.Roche,MP **31**,158-77(1924)

**Brassey's Annuals.** The US Armed Forces year books which are published by W.Clowes & Sons Ltd, London and Macmillan Co, New York. The book published in 1957, edited by H.G.Thursfield et al, marked the 68th year of publication. These vols contain much interesting info, both tech & political in nature

**BRAZILIAN ARMAMENT.** There is no info at our disposal about current Brazil expls, ammo and weapons plants. The material presented here is obsolete, in part

**Brazilian Explosive Plants**

a) *Fâbrica Presidente Vargas* at Piquette, São Paulo State. It is equipped to manuf NG, NC, BkPdr, single- and double- base propInts, dynamites, TNT, sulfuric & nitric acids, ether and probably RDX(Ref 5)

b) *Fâbrica de Estrela*, at Vila Inhomerin, State of Rio de Janeiro. It is equipped to manuf BkPdr, dynamites, primers, fuses and probably RDX

c) *Companhia Nitro Química Brasileira*, at São Miguel, near São Paulo. It is equipped to manuf NC, TNT and nitric & sulfuric acids

d) *Companhia Dinamites do Brasil*, at Rio de Janeiro. It is equipped to manuf dynamites, BkPdr and fuses

e) *DuPont do Brasil SA Industrias Quimicas* (Duperial). It is equipped to manuf NG, NC, dynamites and nitric and sulfuric acids
f)Private Plants at Rio de Janeiro: *Sociedade Anonyma Explsovos "Rupturita", Companhia Nacional Explosivos "Seguranca"* and *Companhia Explosivos "Cheddite"*(Ref 1,p 125)

**Brazilian Weapons**

The following *small-arms*, used in Brazil, are discussed by Smith(Ref 3):
1) *7mm Rifle M1894,Mauser*, very sl modification of the Spanish Mauser M1893; the principal military rifle until it was replaced by the M1904(Ref 2)
2) *7mm Rifle M1904,Mauser*, manuf in Belgium, formerly the principal military rifle; similar in design to the Ger Gewehr 98
3) *7.92mm Rifle,Mauser* manufd in Ger
4)*0.30-06 US Service Rifle*
5) *11mm(0.433") Single-Shot Rifle,M1871*, Spanish Remington Breechloader; not in current use
6) *11mm Single-Shot Rifle,M1871,Comblain*, manufd in Belgium

No information at our disposal on Brazilian Artillery Weapons

Pepin Lehalleur(Ref 1,p 470) described Brazilian pyrotechnics and Da Roca Lima(Ref 4) reviewed the characteristics and methods of testing modern expls

*Refs*: 1)Pepin Lehalleur(1935), 125 & 470 2)M.M. Johnson,Jr,"Rifles and Machine Guns", W.Morrow, NY(1944),73 3)W.H.B.Smith,"The NRA Book of Small Arms", Military Service Pub co, Harrisburg, Pa, vol **2**, "Rifles"(1952),125-6 4)G.daRocaLima, RevBrasilQuim(Sao Paulo) **33**,205-16(1952) & CA **47**,319(1954) 5)Maj W.H.Gross,Explosivst **1956**, 169

**Breadbasket Bomb.** See under BOMBS

**Breaking Theory of Detonation.** Carl(Ref 1) defines detonation as the progressive breaking of valence bonds by distortions, transmitted as elastic waves which are maintained by the energy released by recombination of the initial products of deton. The theory proposed is based on the sensitiveness or tendency of molecules to undergo chem breakdown. According to Carl, the shattering effect of expls does not depend on rate of deton but is largely dependent on the reactivity of the initial products of deton. Materials which are easily detonated are the truly elastic materials(crystals). Any state of matter or agency which tends to prevent distortion of the molecule or crystal will also reduce sensitivity, therefore, all materials which tend to damp out elastic waves will transmit deton imperfectly. The progressive breaking of valence bonds or deton wave may be transmitted thru any material and may, therefore, be considered a universal phenomenon

The primary detong expls are crystalline compds having multiple bonds, which are shown by Carl (Ref 2) to be weaker than expl compds having single bonds. Compds having such bonds are inherently under a strain and have a "certain rigidity". The inherent strained condition of the primary detong expls can be increased by the application of pressure from an outside source. The more sudden the application of pressure the greater the breaking effect. Even tough and plastic materials can be broken by extremely sudden impact. The expls which are crysts and have multiple bonds are most susceptilbe to breaking and also to deton. The breaking force required for deton of insensitive expls can be reliably supplied only by the deton of primary expl compds which produce an extremely sudden and intense impulse. The fact that different primary detong compds will produce impulses of different amplitude, frequency and intensity is offered as an explanation of the selected effectiveness of initiators for different secondary expl compds
*Refs*: 1)L.R.Carl,JFrankInst **230**,75-94,207-27 & 355-74(1940) & CA **34**,6449 & 8283(1940) 2)L.R. Carl,JFrankInst **235**,553-75(1943) & CA **37**,4900 & 6131(1943)

**Breakup Pressure**(Rocket or JATO). See under Burning Time of a Rocket(or JATO) Motor

**Breech.** The rear part of a cannon, or other firearm, aft of the bore(qv)
*Ref*: Merriam-Webster's(1961),274

**Breechblock.** The principal part of the breech *mechanism*(qv) and is essentially a large heavy piece which accurately closes or covers the back end of the barrel. The three general types are: a)Interrupted-screw type, called by Hayes slotted -screw type(Ref 1) b)Eccentric-screw(Nordenfeld) type and c)Sliding-wedge type(See also Breech Mechanism)
*Ref*: 1)Hayes(1938),212-18 2)Anon,"Fundamentals of Artillery Weapons",TM **9-2305**(1947),11-17

**Breechflash.** See Backflash

**Breechloader.** A firearm or an artillery weapon that is loaded at the breech instead of at the

muzzle(See also Breech-loading Weapon)

**Breech-loading**(adj). Receiving the chge at the breech. The action or method of loading at the breech
*Ref*: Merriam-Webster's(1961),274

**Breech-loading Cannon.** See under Breech-loading Weapon

**Breech-loading Rifle.** See under Breech-loading Weapon

**Breech-loading Weapon.** A firearm or an artillery weapon that is loaded through the breech and not through the muzzle as was done in ancient weapons Attempts to introduce breech-loading firearms were made as early as the 16th century when matchlock arms were in use. A sample of such an arm, dated 1537, is in the London Tower Museum. This and other early breech-loaders were not successful due to the lack of good seal(Ref 4,p 11). Some breech-loaders were invented in the era of the flintlock, eg, the Ital "Chamber Piece" of 1694(Ref 4, p 20). The Amer flintlock Hall rifle patented in 1811, may be considered as the first reasonably successful breech-loader to be extensively used. Originally a flintlock, it was adapted to the percussion and rim-fire systems in later years. Hall (Ref 4,p 20) developed his rifle without being aware that similar systems were being experimented with in Europe, among others, by Pauly(1808) & (1812), Degoubert(1818), Robert (1830) and Demondion(1831) (Ref 1,pp 96 & 101)

The European systems at that time were not successful, however, until the appearance, ca 1836, of the so-called *needle gun*(Zündnadelgewehr in Ger), invented by J.N.von Dreyse(Ref 2,p 43 & Ref 3,p 24). This gun used paper cartridges and, although it was rapid-firing(in comparison with muzzle-loaders), its range was short. Real success with breech-loaders was achieved when paper cartridges were replaced by those made of metal, as was done in the Brit breech-loader "Enfield", converted from an old muzzle-loader(Ref 2,p 44). Other early successful breech-loaders were: Norwegian carbine(1842), Karl d'Abezz rifle (Swiss) (1851), Mousqueton de Cent Gardes(Fr) 1860) and Westley-Richards rifle(adopted in 1861 by the Brit cavalry). In 1865, Snider invented a device which permitted conversion of the Brit Enfield muzzle-loaders into breech-loaders. The French also converted their muzzle-loaders with a modification of the Snider device and called it the *tabatière*. One of the most successful breech-loaders of the 19th century was the Martin-Henri rifle used by the British for many years(Ref 2,pp 102-5, 113 & 117). Other 19th century successful breech-loaders were: Braendlin-Albini(Belg), Mauser(Ger), Roberts(US), Chassepot(Fr) and Berdanka(Rus)(Ref 2,pp 125-31 & 135)

At present, breech-loading rifles are used in all countries not only for military but also for sporting purposes

The early attempts to devise a bronze breech-loading cannon were unsuccessful because the backward pressure of the gas ultimately blew out the breech-block or else the gas created sufficient pressure against the walls of the barrel to burst it. As forged-alloy steels were perfected, breech-loading became a more practical possibility; at the same time steel hoops or outer tubes were shrunk onto the barrel to strengthen it, or, at a later date, wire was wound around the barrel at high tension(Ref 2,p 83)

According to EncyclBritannica(Ref 3,p 467), the first fairly successful breech-loading cannons were those of Cavalli, Sardinian officer and of Baron Wahrendorff of Sweden(ca 1840). Still more successful were the guns developed during the '60s and '70s by C.Ragon de Bange(France), Alfred Krupp(Germany), Freyre(Spain) and Broadwell(US). By the end of the 19th century breech-loading cannons were perfected and only very few improvements have been made since that time. Howitzers are also breech-loading weapons. The only artillery weapons which are muzzle-loaded are light mortars (See also Breech Mechanisms)
*Refs*: 1)W.W.Greener, "The Gun and Its Development", Cassell, Petter, Galpin & Co, London(1885), 96-216 2)J.R.Newman, "Tools of War", Doubleday, Doran & Co, New York(1943),43-4 & 83 3)Encyclopedia Britannica 2(1952),467(under Artillery) 4)W.H.B.Smith, "Small Arms of the World", Military Service, Publishing Co, Harrisburg, Pa(1960),12 & 20

**Breech Mechanism.** The assembly at the rear of a gun which receives the round of ammo, inserts it into the chamber, fires the round by detong the primer and extracts the empty case(Refs 1,4 & 5). Breech mechanisms may be divided into: a)Carrier-type and b)Tray-type operating mechanisms(Ref 3,p 17)

Safety devices, to prevent accidental firing or firing before the breech is closed, are normally found on the breech mechanism. These devices consist of levers or latches which function automatically. Detailed description of breech mecha-

nisms are given in Refs 2 & 3. The Bofors rapid -fire breech mechanism is described in Ref 2,pp 218-19
*Refs*: 1)M.B.Garber, "A Modern Military Dictionary", Garber,Washington,DC(1936),49 2)Hayes(1938) 212-40 3)Anon, "Fundamentals of Artillery Weapons", TM **9-2305** (1947),11-41 4)Glossary of Ord(1959) 49 5)Merriam-Webster's(1961),274

**Breech Obturation.** A device that will prevent powd gases from passing to the rear into threads and other parts of the breech mechanism. In guns that use fixed or semi-fixed ammo, the obturation is performed by the cartridge case, which expands under pressure in the bore to form a tight seal against the walls of the gun. In weapons using separate-loading ammo, a device must be included in the breech mechanism. For this purpose, the Debange Obturator is used exclusively in US weapons
*Refs*: 1)Hayes(1938),224 2)TM **9-2305**(1947),35

**Breech Piece.** The jacket of a heavy gun. In the later Krupp gun, it receives the breechblock(qv) and relieves the central tube of longitudinal stress
*Ref*: Merriam-Webster's(1951),332

**Breech Screw.** In muzzle-loading muskets and rifles, a solid screw plug closing the bottom of the bore
*Ref*: Merriam-Webster's(1951),332

**Breech Sight.** The rear sight of a gun, usually mounted near the breech
*Ref*: Garber(1936),49

**Bren Machine Gun.** A light machine gun, widely used in WWII, developed in Czechoslovakia and designed for infantry use. It was adopted as a std weapon by GtBrit & other countries
*Refs*: 1)M.B.Garber, "A Modern Military Dictionary", Garber,NY(1936),50 2)W.W.Holler,Edit, "Glossary of Ordnance Terms",OEHO(1959),49

**Brenzcatechin or Brenzöl**(Ger). See Pyrocatecol

**Bresin Resin**(Bresinharz in Ger). A raw material for NC lacquers & synthetic materials, described in Refs 1 & 2
*Refs*: 1)W.Schmandt,NC **7**,5-7(1936) 2)W.Delaney, NC **7**,219-20(1936)

**Bridge Wire.** A small diam corrosion-resistant wire which is attached across the terminals of insulated leg wires. This device constitutes the elec firing element in an elec blasting cap(qv). Upon application of elec current, the bridge heats to incandescence and fires the ignition chge in the cap(Ref 4)

Piccard(Ref 1) patented a bridge wire for blasting caps. It consisted of gold ca 58.4 & nickel ca 41.6% alloyed together and drawn to the req size to have a desired elec resistance per unit length. Bremer(Ref 2) patented a bridge wire alloy which consisted of rhodium, ruthenium and platinum in the proportions of 2-25% rhodium, 2-25% ruthenium and the balance platinum. Nash(Ref 3) patented an elec firing device which includes in combination, a casing, an expl chge and a firing assembly adjacent to the chge. The firing assembly consisted of a pair of leg wires disposed in spaced relationship to each other and connected to a bridge wire. The bridge wire is made of zirconium and has a metallic oxide adhering to the wire whereby the bridge wire is caused to be pyrophorized under a relatively low elec potential during a relatively short time
*Refs*: 1)J.Piccard,USP 1926213(1933) 2)B. Bremer,USP 2080110(1937) 3)H.E.Nash,USP 2320880(1943) 4)Blasters' Hdb(1952),93-4

**Bridge Wire Lag.** When an elec current passes through a bridge wire of devices such as elec detonators or blasting caps, there is a certain interval(lapse of time) between the application of current and the breaking(fusion) of the bridge wire. This period of time is called "bridge wire lag"

This phenomenon is dependent upon the firing current used since the bridge wire will fuse in a short time at higher amperage than at lower amps. For many practical purposes, bridge wire lag is not significant since in seismographic explns and other types of work requiring fast caps, the instant the bridge wire breaks or fuses can be assumed to be the instant of deton. A far more serious factor affecting the overall time lag is the interval of time between the breaking of the bridge wire and the actual deton of the cap. This lag, called "*induction period*", depends to a certain extent upon the firing circuit used. For example, at high amperages, such as 20amps, the bridge wire lag for a given ign compn will be shorter and consequently the induction period will usually be longer than at lower amperages, such as 5 amps. At a given amperage, however, the induction period is a definite characteristic property of the ign compn employed. Thus, certain ign materials have an inherently long induction

period

The use of very fast ign agents involves, in most cases, considerable danger from the hazard of static elecy. It has been found that ign compds which have a negligible induction period(or so -called fast compds) are susceptible to initiation by static elecy. Particularly susceptible to static elecy is Cu acetylide

*Ref*: W.H.Aughey, L.A.Burrows & W.E.Lawson, USP 2086527(1937) & CA **31**,6466(1937)

**Brigg's Explosive.** K chlorate 65.5, MNB 20.5 & BkPdr 14.0%

*Refs:* 1)F.H.Briggs,USP 934990(1909) 2)Colver (1919),673

**Brimstone.** The coml name for crude sulfur

*Refs*: 1)Hackh's (1944),143 2)Merriam-Webster's (1951),337

**Brine.** Water which is nearly saturated with salts, such as NaCl

*Ref*: Hackh's(1944),143

**Briner Method of Ozonization of Organic Compounds.** See under Ozonization of Organic Compounds

**BRISANCE OR SHATTERING EFFECT**(Brisance in Fr, Brisanz in Ger, Brizantnost' in Rus, Dirompenza in Ital, Poder rompedor in Span)

When an explosive detonates, tremendous pressure is released practically instantaneously in a shock wave which exists only a fraction of a second at any given place. The subsequent expansion of gases performs work but the sudden pressure thus created will shatter rather than displace any object in its path. The ability of an expl to demolish(fragment, shatter) a solid object (such as steel, concrete, stone) when fired in direct contact with it or in its vicinity is called *brisance* (from the French "briser"= to break or shatter). From a military viewpoint brisance is of practical importance because it determines the effectiveness of an explosive in fragmenting shells, bomb casings, grenades, mines, etc and in imparting high velocities to the resulting fragments. As the shattering effect is dependent upon the suddenness with which the gaseous products of an expl are liberated, the velocity of detonation is at least a major factor in determining brisance. It has been found that there is a general linear relationship between velocity of detonation and brisance, and if the velocity is known it is possible to calculate the brisance or vice versa(as will be shown below under "Brisance-Detonation Velocity Relationship")

Brisance may also be calcd from the formula of Kast(see below) or determined experimentally by one of the methods listed under "Brisance, Experimental Determinations"

Since brisance is approx proportional to detonation velocity, "force" and density of loading, Kast proposed to determine it by the following equation:

B = f × d × D, where B is brisance value (Brisanzwert in Ger), d is density of charge, D detonation velocity in m/sec and f "specific energy or force", also called "specific pressure" and in Fr "force spécifique de Sarrau". The Germans call it "spezifische Kraft oder Energie". The force is expressed in kg/cm$^2$ and is equal to $p_o \times v_o \times T/273$, where $p_o$ is atmospheric pressure expressed as 1.033kg/cm$^2$, $v_o$ volume of gases developed on expln in cc per g of expl reduced to 0°C and 760mm Hg pressure and T is the max absolute temp of expln. On substituting for f, in the above expression, the following equation is obtained: $B = p_o \times v_o \times T/273 \times d \times D$

In the above equation T is equal to t+273 or to $Q_e/c + 273$ where $Q_e$ is the heat of expln in cal/g and c is the mean specific heat of the products of expln in cal/g

As an example, for blasting gelatin(NG 92 & NC 8%),Stettbacher(Ref 10,p 49) gives: $p_o$ = 1.033, $v_o$ = 711.4cc per g, t = 4410°C, d 1.60 and D = 7500m/sec. This gives:

$$B = 1.033 \times 711.4 \times \frac{4410 + 273}{273} \times 1.6 \times 7500 = 151.2 \times 10^6$$

Kast's values for many expls are given in Refs 1,2,3,4,5,5a,6,7,8,9,10,11,13,14,15 & 17. They are listed in the appended table in conjunction with detonation velocities and brisance values determined experimentally by several methods evolved on deton and D the detonation velocity. However, practical tests do not confirm the idea that B is proportional to the square of the deton velocity but that simple proportionality(as in the formula of Kast) agrees better with the facts(see Ref 2,p 476). Friederich(Ref 10a) introduced the term "specific brisance" and proposed to calc it from the formula $(D^2_{max} \times \Delta)/100$ kg/cm$^2$, where $D_{max}$ is maximum detonation velocity and $\Delta$ specific gravity in g/cc. The following table compares "specific brisance" with Kast's brisance values:

See Table on Next Page

| Explosive | Kast's B Value | Specific B, kg/cm$^2$ | Max Deton Vel,m/sec |
|---|---|---|---|
| TNT | $86.2\times10^6$ | 862000 | 7200 |
| PA | $107.4\times10^6$ | 1034000 | 7650 |
| Tetryl | $114.9\times10^6$ | 1117000 | 8050 |
| PETN | $183.7\times10^6$ | 1286000 | 8525 |

It should be noted that brisance is a very complicated phenomenon and that none of the existing methods of calcn, such as by Kast's formula(see above), Herlin's formula(Refs 1a & 12), Bichel's formula, Friederich's formula(Ref 10a), etc or of experimental determinations gives exact interpretation of B. The matter of detg it is complicated by the fact that the B of a cartridge of expl is different in different directions: if a cylindrical cartridge is detonated from one end, the action in the direction in which deton proceeds is considerably greater than that in the opposite direction

According to Cook(Ref 29,p 34) the term brisance was used to describe the property now attributed to *detonation pressure*. This property may in many cases be calculated from fundamental physical laws

For a condensed explosive the detonation pressure $p_2$ may be approx calcd from the equation: $p_2 = 0.00987\ \rho_1 D^2/4$ where $\rho_1$ is the original density and D the detonation velocity in m/sec. A more accurate equation is also given by Cook (Ref 29,p 35)

Lothrop & Handrick in an article(Ref 26a) discussing the relationship between performance and constitution of pure organic compounds included curves showing the relationship between power & brisance and oxygen balance of many organic explosives

Price(Ref 31), in discussing the dependence of damage effects upon detonation parameters of organic high explosives, substituted the term *detonation pressure* for brisance and *detonation energy* for power. She also stated that from data obtained at NOL, it has been possible to show that fragment velocity, shaped charge penetration, airblast, and underwater effects are related to the explosive properties of detonation pressure and detonation energy. For more info on this subject see Ref 31

A table giving Brisance, by various methods, as well as Detonation Velocity and Power precedes Refs (See also Brisance-Detonation Velocity Relationship, which follows Refs)

**Table 1**

Comparison of Brisance Values Calculated by Kast's Formula, Relative Brisance Values Obtained by Various Experimental Procedures; Detonation Velocities and Power Determined by Various Methods for Principal Explosives

| Explosive | Brisance by Kast B ($\times 10^6$) | Brisance Relative %TNT | Density d g/cc | Method of Detg | Brisance Relative %TNT | Density d g/cc | Deton Velocity m/sec | Density d g/cc | Power Method of Detg | Power Relative %TNT |
|---|---|---|---|---|---|---|---|---|---|---|
| Abel(or Picric) Powder (Brit)($KNO_3$ 57 & AmmP 43%) | – | – (See also Vol 1,p Al-R) | – | | – | – | 3500 (Ref 24,p 104) | – | BMT | 75 |
| Aldorfit(AN 81,TNT 17 & woodmeal 2%) | – | – | – | CCCT | ca 65 | 1.05 | 4500 | 1.05 | TT | 129 |
| Alumatol(AN 77,TNT 20 & Al 3%) | | (See also Vol 1,p A141-R) | | | Expl characteristics sl higher than those for Amatol 80/20 | | | | | |
| Amatex 9(AN 50,TNT 41 & RDX 9%) | | (See also Vol 1,p 157-R) | | | Expl characteristics higher than for Amatol 60/40 | | (Ref 24,p 133) | | | |

Abbreviations: **BMT**-Ballistic Mortar Test; **BPT**-Ballistic Pendulum Test; **CCCT**-Copper Cylinder Compression Test; **FET**-Fragmentation Efficiency Test; **FGT**-Fragment Gun Test; **LBCT**-Lead Block Compression Test; **PCT**-Plate Cutting Test; **PDT**-Plate Denting Test; **ST**-Sand Test and **TT**-Trauzl Test (Lead Block Expansion Test)

*Notes:* Most Sand Test values listed in this table were detd for 0.4g samples compressed at 3000 or 3400psi. Their densities were not determined except in a few cases

| Explosive | Brisance by Kast B ($\times 10^6$) | Brisance Relative %TNT | Density d g/cc | Brisance Method of Detg | Brisance Relative %TNT | Density d g/cc | Deton Velocity m/sec | Density d g/cc | Power Method of Detg | Power Relative %TNT |
|---|---|---|---|---|---|---|---|---|---|---|
| Amatol 80/20(AN 80 & TNT 20%) | – | – | – | ST | 74 | – | 5300 | 1.6 | TT | 126 |
| | | | | | | | | | BMT | 130 |
| Amatol 60/40(AN 60 & TNT 40%) | – | – | – | ST | 90 | – | 6200 | 1.6 | BMT | 128 |
| | | | | FET | 81 | 1.53 | | | | |
| Amatol 50/50(AN 50 & TNT 50%) | – | – | – | ST | 90 | – | 6400 | 1.59 | BMT | 123 |
| | | | | FET | 82 | 1.55 | | | TT | 116 |
| Amatol 40/60(AN 40 & TNT 60%) | 77.1 | 89 | 1.56 | ST | 94 | – | 6550 | 1.6 | TT | 120 |
| | | | | CCCT | 81 | 1.56 | | | | |
| 5-Aminotetrazole Nitrate | – | – | – | – | – | – | – | – | TT | 117 |
| | (See also Vol 1,p 259-R) | | | | | | | | | |
| Ammonal(Austrian) (AN 46,TNT 30,Al 22 & brown coal 2%) | 85.5 | 99 | 1.60 | CCCT | 78 | 1.60 | – | – | – | – |
| Ammonal(Brit)(AN 65, TNT 15,Al 10 or 17 & charcoal 10 or 3%) | – | – | – | ST | 47 | – | 3300 (Ref 24,pp 85-6) | 1.6 | BMT | 122 |
| Ammonal(US)(AN 22, TNT 67 & Al 11%) | | – | – | ST | 100 | – | – | – | BMT | 122 |
| | | | | FET | 108 | 1.42 | | | | |
| Ammonium Cre sylite | See Ekrasit | | | | | | | | | |
| Ammonium Methylenedi-nitramine | – | – | – | – | – | – | – | – | BMT | 142 |
| Ammonium Nitrate(AN) | 17 | 19.7 | 1.3 | ST | No expln | | 2800 | 1.0 | TT | 75 |
| [See also Vol 1,pp A321-L, A321(table) and A325-R] | | | | LBCT | 55 | 1.3 | | | BMT | 79 |
| Ammonium Nitrate/Al /TNT-81/ 10/9 | – | – | – | – | – | – | – | – | BMT | 136 |
| Ammonium Nitrate /EDNA/TNT-60/20/20 | – | – | – | – | – | – | – | – | BMT | 135 |
| Ammonium Nitroform | – | – | – | – | – | – | – | – | TT | 128 |
| Ammonium Perchlorate | 17 | 19.7 | 1.2 | ST | No expln | | 3000 | 1.3 | BMT | 100 |
| | 30.6 | 35.8 | 1.3 | | | | | | | |
| Ammonium Picrate(AmmP) (Explosive D or Dunnite) | – | – | – | ST | 84-7 | – | 7000 | 1.6 | BMT | 98-99 |
| | | | | PDT | 91 | 1.50 | | | | |
| | | | | FET | 96 | 1.53 | | | | |

See page B 266 for the meaning of Abbreviations

| Explosive | Brisance by Kast B ($\times 10^6$) | Brisance Relative %TNT | Density d g/cc | Brisance Method of Detg | Brisance Relative %TNT | Density d g/cc | Deton Velocity m/sec | Density d g/cc | Power Method of Detg | Power Relative %TNT |
|---|---|---|---|---|---|---|---|---|---|---|
| Ammonium Trinitrocresylate/Potassium Nitrate | Expl characteristics are lower than those of PA<br>*Note*: According to Pepin-Lehalleur(Ref 14,p 374) this mixt is Austrian military expl Ecrasite but Stettbacher(Ref 27a,p 77) claimed that Austrian Ekrasit consisted of PA with small amts of DNN or DNB | | | | | | | | | |
| Anhydroenneaheptitol Pentanitrate | | | | Brisance > PETN | | | | | BMT | 134-7 |
| Azidoethylnitrate | – | – | – | – | – | – | 6550 | 1.34 | TT | 161-70 |
| Azidohydroxytetrazole | – | – | – | – | – | – | – | – | TT | 89 |
| Baratol(Ba nitrate 67 & TNT 33%) | – | – | – | ST<br>PDT | 56<br>61 | –<br>2.52 | – | – | – | – |
| Baratol(Ba nitrate 10 & TNT 90%) | – | – | – | ST | 84 | – | 5900 | 1.65 | TT<br>BMT | 98<br>98 |
| Baronal(Ba nitrate 50, TNT 35 & Al 15%) | – | – | – | ST | 83 | – | 5450 | 2.32 | BMT | 90-96 |
| Benzenehexamethanol Hexanitrate | Its expl characteristics are given in classified A.D.Little,Inc Reports | | | | | | | | | |
| Bis(2,2,2-trinitroethyl) -nitramine(BTNEU or HOX) | See Di(2,2,2-trinitroethyl)-nitramine | | | | | | | | | |
| Bis(2,2,2-trinitroethyl) -urea(BTNEU) | See Di(2,2,2-trinitroethyl)-urea | | | | | | | | | |
| Black Powder(K nitrate 75,charcoal 15 & sulfur 10%) | – | – | – | ST | 22 | – | 400 | 1.6 | TT<br>BMT | 10<br>45 |
| Blasting Gelatin (NG 92 & NC 8%) | 156.3<br>151.2 | 182<br>176 | 1.63<br>1.60 | PDT<br>CCCT | 113<br>133 | 1.55<br>1.63 | 8000 | 1.55 | TT | 194 |
| Blasting Gelatin with 31% Al | – | – | – | – | – | – | 7000 | 1.9 | – | |
| Boronite B(AN 75, TNT 20 & boron 5%) | – | – | – | ST<br>FET | 82.5<br>85 | –<br>1.35 | – | – | BMT | 118 |
| Borotorpex(RDX 46,TNT 44 & boron 10%) | – | – | – | PDT | 127 | 1.74 | 7600 | 1.74 | BMT | 129 |
| BSX | See 1,7-Diacetoxytetramethylene-2,4,6-trinitramine | | | | | | | | | |

See page **B 266** for the meaning of Abreviations

| Explosive | Brisance by Kast B ($\times 10^6$) | Brisance Relative % TNT | Density d g/cc | Brisance Method of Detg | Brisance Relative % TNT | Density d g/cc | Deton Velocity m/sec | Density d g/cc | Power Method of Detg | Power Relative % TNT |
|---|---|---|---|---|---|---|---|---|---|---|
| BTM(Tetryl 55,TNT 25 & Al 20%) | – | – | – | FET | 107 | 1.77 | – | – | – | – |
| BTNEN | Abbreviation of Bis(2,2,2-trinitroethyl)-nitramine It is listed in this table as Di(2,2,2-trinitroethyl)-nitramine | | | | | | | | | |
| BTNEU | Abbreviation of Bis(2,2,2-trinitroethyl)-urea. It is listed in this table as Di(2,2,2-trinitroethyl)-urea | | | | | | | | | |
| Burrowite(Brit)(AN 74, TNT 16 & Al 10%) | Expl characteristics comparable to Ammonal(US) | | | | | | | | | |
| 1,2,3-Butanetriol Trinitrate | – | – | – | ST | 112 | 1.5 | – | – | – | – |
| 1,2,4-Butanetriol Trinitrate | – | – | – | ST | 101 | 1.52 | – | – | BMT | 140 |
| Butyleneglycol Dinitrate | – | – | – | – | – | – | – | – | TT | 130-50 |
| CE (Brit) | See Tetryl | | | | | | | | | |
| Cheddite($KClO_3$ 79,DNT 15, castor oil 5&MNN 1%) | 37.6 | 44 | 1.3 | CCCT | 48-64 | 1.3 | 3000 | 1.3 | TT | 88-92 |
| Composition A(or A-3) (RDX 91 & wax 9%) | – | – | – | ST<br>PDT<br>FET | 107-15<br>126<br>150 | –<br>1.61<br>1.63 | 8200 | 1.60 | TT<br>BMT | 144<br>132-5 |
| Composition A,Aluminized (RDX 73,Al 18 & wax 8%) | – | – | – | PDT | 110 | 1.72 | 7800 | 1.70 | BMT | 142 |
| Composition B(RDX 60 & TNT 40% with 1% wax added) | – | – | – | ST<br>PDT<br>FET | 112-21<br>129-32<br>139 | –<br>1.66-1.72<br>1.65 | 7790 | 1.68 | TT<br>BMT | 131<br>134 |
| Composition C(US);PE-2 (Brit)(RDX 88.3 & non-expl oil contg 0.6 lecithin 11.7%) | – | – | – | ST<br>PDT | 108<br>112 | –<br>1.58 | 7400 | 1.50 | TT<br>BMT | 126<br>125 |
| Composition C-2(RDX 78.7, TNT 5.0,DNT 12.7, MNT 2.7,NC 0.6 & solvent 1%) | – | – | – | ST<br>PDT | 99<br>111 | –<br>1.52 | 7800 | 1.57 | BMT | 126-43 |
| Composition C-3(RDX 77, Tetryl 3,TNT 4,DNT 10, MNT 5 & NC 1%) | – | – | – | ST<br>PDT<br>FET | 112<br>114-18<br>133 | –<br>1.57<br>1.59 | 7625 | 1.60 | TT<br>BMT | 117<br>126 |

See page B 266 for the meaning of Abbreviations

| Explosive | Brisance by Kast B ($\times 10^6$) | Relative %TNT | Density d g/cc | Brisance Method of Detg | Relative %TNT | Density d g/cc | Deton Velocity m/sec | Density d g/cc | Power Method of Detg | Relative %TNT |
|---|---|---|---|---|---|---|---|---|---|---|
| Composition C-4[RDX 91, polyisobutylene 2.1, motor oil 1.6 & di(2-ethyl) sebacate 5.3%)] | – | – | – | ST<br>PDT | 116<br>115-30 | –<br>1.60 | 8040 | 1.59 | BMT | 130 |
| Copper Chlorotetrazole | – | – | – | ST | 53 | – | – | – | – | – |
| Cresylite (Kresilit) | See Trinitrocresol | | | | | | | | | |
| Cyanuric Triazide | 70.7<br>122 | 82<br>142 | 1.20<br>1.54 | ST | 99 | – | 7500 | 1.54 | TT<br>BMT | 140-5<br>145 |
| Cyclofive (RDX 53 & Fivonite 47%) | – | – | – | PDT | 124 | cast | – | – | BMT | 134 |
| Cyclonite | See Cyclotrimethylenetrinitramine | | | | | | | | | |
| Cyclotetramethylene-tetranitramine (HMX) (beta) | – | – | – | ST | 125-55 | – | 9124 | 1.84 | TT<br>BMT<br>BPT | 159-65<br>150<br>170 |
| Cyclotol 75/25(RDX 75 & TNT 25%) | – | – | – | ST | 130 | – | 8035 | 1.70 | BMT | 137 |
| Cyclotol 70/30(RDX 70 & TNT 30%) | – | – | – | ST<br>PDT<br>FFT | 128<br>136<br>163 | –<br>1.72<br>1.71 | 8060 | 1.72 | BMT<br>TT | 135<br>145 |
| Cyclotol 65/35 (RDX 65 & TNT 35%) | – | – | – | ST | 126 | – | 7974 | 1.72 | BMT | 133 |
| Cyclotol 60/40 (RDX 60 & TNT 40%) | – | – | – | ST<br>PDT | 125<br>132 | –<br>1.72 | 7900 | 1.72 | BMT | 130 |
| Cyclotol 55/45 (RDX 55 & TNT 45%) | – | – | – | – | – | – | – | – | BMT | 127 |
| Cyclotol 40/60 (RDX 40 & TNT 60%) | – | – | – | – | – | – | 7485 | 1.68 | BMT | 123 |
| Cyclotol 30/70 (RDX 30 & TNT 70%) | – | – | – | ST | 112 | – | – | – | BMT | 115 |
| Cyclotrimethylenetri-nitramine (Cyclonite, RDX or Hexogene) | 188 | 218 | 1.70 | ST<br>CCCT<br>PCT<br>PDT | 140<br>144<br>125<br>135-41 | –<br>1.70<br>1.70<br>1.71 | 8270 | 1.675 | TT<br>BMT | 170<br>150 |

See page B 266 for the meaning of Abbreviations

| Explosive | Brisance by Kast B ($\times 10^6$) | Brisance Relative % TNT | Density d g/cc | Brisance Method of Detg | Brisance Relative % TNT | Density d g/cc | Deton Velocity m/sec | Density d g/cc | Power Method of Detg | Power Relative % TNT |
|---|---|---|---|---|---|---|---|---|---|---|
| Cyclotrimethylenetrinitrosoamine or R-Salt (Ger R-Salz) | – | – | – | ST | 102-18 | – | 7300<br>7000 | –<br>1.42 | TT<br>BMT | 122-6<br>134 |
| | *Note*: Other expl characteristics are given in Ref 30a,p 354(Conf) [See also PATR **2510**(1958),p Ger 170(R-Salz) and OSRD **2014**(1944)] | | | | | | | | | |
| DBX (Depth Bomb Explosive) (RDX 21, AN 21, TNT 40 & Al 18%) | – | – | – | ST<br>PDT | 121<br>102 | –<br>1.76 | 6800 | 1.68 | BMT | 146 |
| Dentex (RDX 48, DNT 34 & Al 18%) | Expl characteristics not found; was developed as a substitute for Torpex-2 (Ref 24b,p 33) | | | | | | | | | |
| 1,7-Diacetoxytetramethylene-2,4,6-trinitramine | – | – | – | – | – | – | – | – | TT<br>BMT | 85<br>120 |
| Diaminotrinitrobenzene | See Ref 30a,p 361(Conf) | | | | | | | | | |
| Diazodinitrophenol (DADNPh) | – | – | – | ST<br>LBCT | 97-104<br>71 | – | 7100 | 1.63 | TT | 105-10 |
| Diethanolnitramine Dinitrate(DINA) | – | – | – | ST<br>PDT | 71<br>119 | –<br>1.50 | 7800 | 1.6 | TT<br>BMT | 160<br>140-58 |
| Diethyleneglycoldinitrate (DEGDN) | – | – | – | ST | 95 | 1.38 | 6800 | 1.38 | TT<br>BMT | 134-58<br>127-37 |
| Diethyleneglycoldinitrate/Nitroglycerin -50/50 | – | – | – | ST | 165 | 1.5 | – | – | – | – |
| 2,6-Dimethylol-2,6-dinitro-1,7-heptanediol Tetranitrate | – | – | – | – | – | – | – | – | BMT | 138 |
| 2,5-Dimethylol-2,5-dinitro-1,6-hexanediol Tetranitrate | – | – | – | – | – | – | – | – | BMT | 147 |
| DINA | See Diethanolnitraminedinitrate | | | | | | | | | |
| Dinitraminoisopropylnitrate | – | – | – | – | – | – | – | – | BMT | 142 |
| 1,3-Dinitramino-2-propanol Nitrate | – | – | – | – | – | – | – | – | BMT | 142 |

See page **B 266** for the meaning of Abbreviations

| Explosive | Brisance by Kast B ($\times 10^6$) | Brisance Relative %TNT | Density d g/cc | Brisance Method of Detg | Brisance Relative %TNT | Density d g/cc | Deton Velocity m/sec | Density d g/cc | Power Method of Detg | Power Relative %TNT |
|---|---|---|---|---|---|---|---|---|---|---|
| Dinitroaniline(DNA) | – | – | – | – | – | – | – | – | BMT | 88 |
| Dinitroanisole(DNAns) | – | – | – | – | – | – | – | – | BMT | 87 |
| Dinitrobenzene(DNB) | 64 | 74 | 1.50 | ST<br>CCCT | 74-82<br>80 | –<br>1.50 | 6100 | 1.56 | TT<br>BMT | 79-86<br>90 |
| 2,6-Dinitro-2,6-bis-hydroxymethyl-1,7-heptanediol Tetranitrate | See 2,6-Dimethylol-2,6-dinitro-1,7-heptanediol Tetranitrate | | | | | | | | | |
| 2,5-Dinitro-2,5-bis-hydroxymethyl-1,6-hexanediol Tetranitrate | See 2,5-Dimethylol-2,5-dinitro-1,6-hexanediol Tetranitrate | | | | | | | | | |
| Dinitrochlorohydrin | See Glycerol Monochlorohydrin Dinitrate | | | | | | | | | |
| Dinitrodichlorobenzene (Parazol) | – | – | – | LBCT | 69 | 1.69 | – | – | BMT | 86 |
| Dinitrodimethyloxamide (MNO) | – | – | – | ST<br>FGT | 71<br>98 | –<br>1.45 | 7050 | 1.5 | TT<br>BMT | 105<br>129-35 |
| Dinitrodimethylsulfamide | – | – | – | – | – | – | – | – | BMT | 126 |
| Dinitrodi($\beta$-nitroxyethyl) oxamide(NENO) | – | – | – | FGT | 116 | 1.62 | 7800 | 1.63 | TT<br>BMT | 145<br>129-35 |
| Dinitroethane | – | – | – | – | – | – | – | – | TT<br>BMT | 150<br>127-42 |
| Dinitroethyleneurea (DNEU) | – | – | – | ST | 109 | – | 7660 | 1.6 | TT<br>BMT | 120<br>130 |
| Dinitrofuran | – | – | – | ST | 90 | – | – | – | – | – |
| Dinitroglycerin | See Glyceroldinitrate | | | | | | | | | |
| Dinitrophenol(DNPh) | – | – | – | ST | 52 | – | – | – | BMT | 52 |
| 3,5-Dinitrophenyl-nitromethane | – | – | – | – | – | – | – | – | TT | ca 100 |
| 2-(3',5'-Dinitrophenyl) -2-nitro-1,3-propanediol Dinitrate | – | – | – | – | – | – | – | – | BMT | 126 |
| 1,4-Dinitropiperazine | – | – | – | – | – | – | – | – | TT<br>BMT | 114<br>107 |

See page B 266 for the meaning of Abbreviations

| Explosive | Brisance by Kast B ($\times 10^6$) | Brisance Relative %TNT | Density d g/cc | Brisance Method of Detg | Brisance Relative %TNT | Density d g/cc | Deton Velocity m/sec | Density d g/cc | Power Method of Detg | Power Relative %TNT |
|---|---|---|---|---|---|---|---|---|---|---|
| 2,2-Dinitropropane | – | – | – | – | – | – | – | – | TT<br>BMT | 130<br>123 |
| 2,2-Dinitro-1-propanol | – | – | – | – | – | – | – | – | BMT | 122 |
| 2,4-Dinitrotoluene(DNT) | – | – | – | LBCT | 77 | 1.3 | – | – | TT<br>BMT | 64<br>71 |
| Di($\beta$-nitroxyethyl) -nitramine | – | – | – | – | – | – | – | – | BMT | 142 |
| Dinitroxypentamethylene tetranitramine("106") | – | – | – | – | – | – | 7895 | 1.35 | BMT | 155 |
| Dipentaerythritol Hexanitrate(DPEHN) | 148 | 172 | 1.63 | ST | 119 | – | 7450 | 1.63 | TT<br>BMT | 128<br>144 |
| Dipicrylamine | See Hexanitrodiphenylamine | | | | | | | | | |
| Dipicrylethylenedi-nitramine | – | – | – | – | – | – | – | – | BMT | 123 |
| Dipicryl Sulfide | See Hexanitrodiphenyl Sulfide | | | | | | | | | |
| Ditetryl (Brit) | See Trinitrodi(methylnitramino)-benzene | | | | | | | | | |
| Ditetryl (US) or Octyl (Brit) | See N,N'-(Hexanitrodiphenyl)-ethylenedinitramine | | | | | | | | | |
| Dithekite(Nitric Acid /Nitrobenzene/$H_2O$) | – | – | – | – | – | – | – | – | TT<br>BMT | 110-24<br>124 |
| Di(2,2,2-trinitroeth yl) -nitramine or B is(2,2,2 -trinitroethyl)-nitramine (BTNENA or HOX) | – | – | – | – | – | – | – | – | TT<br>BMT | 147-8<br>134-55 |
| Di(2,2,2-trinitroethyl) -urea or Bis(2 , 2,2-tri-nitroethyl)-urea(BTNEU) | – | – | – | – | – | – | – | – | TT<br>BMT | 169<br>144 |
| Donarite(AN 80,gelatin-ized NG 4 ,TNT 12 & linseed flour 4%) | 51 | 59 | 1.3 | CCCT | 56 | 1.3 | 4000 | 1.14 | – | – |
| Dulcitol Hexanitrate | – | – | – | – | – | – | – | – | BMT | 145 |
| Dunnite or Explosive D | See Ammonium Picrate | | | | | | | | | |

See page B 266 for the meaning of Abbreviations

| Explosive | Brisance by Kast B (x $10^6$) | Brisance Relative %TNT | Density d g/cc | Brisance Method of Detg | Brisance Relative %TNT | Density d g/cc | Deton Velocity m/sec | Density d g/cc | Power Method of Detg | Power Relative %TNT |
|---|---|---|---|---|---|---|---|---|---|---|
| Dynamite, Guhr, 75%(NG 75%&kieselguhr 25%) | – | – | – | CCCT | 68%NG | 1.50 | 6800 | 1.50 | TT<br>TT | 105<br>59%NG |
| Dynamite, Straight, 60% (NG 56.8, Na nitrate 22.6, woodmeal 18.2, antacid 1.2 & moisture 1.2%) | – | – | – | – | – | – | 5900 | – | BPT | 114 |
| Dynamite, Straight, 50% (NG 49.0, Na nitrate 34.4, woodmeal 34.4, antacid 1.1 & moisture 0.9%) | – | – | – | – | – | – | 5200 | – | BMT | 102.5 |
| Dynamite, Straight, 40% (NG 39.0, Na nitrate 45.5, woodmeal 13.8, antacid 0.8 & moisture 0.9%) | – | – | – | – | – | – | 4400 | – | BPT | 94.5 |
| | (See also Blasting Gelatin and Gelatin Dynamites) | | | | | | | | | |
| Ecrasite | See Ekrasit | | | | | | | | | |
| EDDN | See Ethylenediamine Dinitrate | | | | | | | | | |
| EDNA or Haleite | See Ethylenedinitramine | | | | | | | | | |
| Ednafive(EDNA 50& Fivonite 50%) | – | – | – | PDT | 111 | cast | – | – | BMT | 130 |
| Ednatol, 60/40(EDNA 60 & TNT 40%) | – | – | – | ST<br>FET | 112-7<br>113-41 | –<br>1.62 | 7475 | 1.60 | TT<br>BMT | 117<br>119-21 |
| Ednatol, 55/45(EDNA 55 & TNT 45%) | – | – | – | ST<br>FET<br>PDT | 103<br>124<br>105 | –<br>1.62<br>1.62 | 7340 | 1.63 | TT<br>BMT | 119<br>120 |
| Ednatol, 50/50(EDNA 50 & TNT 50%) | – | – | – | FET<br>PDT | 109<br>105-11 | 1.62<br>1.62 | 7264 | 1.63 | BMT | 112-17 |
| Ednatolal(EDNA 40, TNT 40 & Al 20%) | – | – | – | – | – | – | – | – | BMT | 130 |
| Ekrasit(Ecrasite) | See Note under Ammonium Trinitrocresylate/Potassium Nitrate | | | | | | | | | |
| EMMET | See Ethyltrimethylolmethane Trinitrate | | | | | | | | | |
| Erythritol Tetranitrate (Tetranitroerythrite) | – | – | – | ST | 132-43 | – | – | – | BMT | 151 |
| Ethanolnitramine(NENA) | See N-(β-Nitroxyethyl)-nitramine | | | | | | | | | |

See page **B 266** for the meaning of Abbreviations

| Explosive | Brisance by Kast B ($\times 10^6$) | Brisance Relative %TNT | Density d g/cc | Brisance Method of Detg | Brisance Relative %TNT | Density d g/cc | Deton Velocity m/sec | Density d g/cc | Power Method of Detg | Power Relative %TNT |
|---|---|---|---|---|---|---|---|---|---|---|
| Ethylenebis(ethanol-nitramine)-dinitrate | – | – | – | – | – | – | – | – | BMT | 134 |
| Ethylenediamine Dinitrate(EDDN) | – | – | – | ST<br>PDT | 96<br>101 | –<br>1.525 | 4940 | 0.9 | TT<br>BMT | 121<br>112-28 |
| EDDN/AN-50/50 | – | – | – | PDT | 51 | 1.60 | – | – | BMT | 123 |
| EDDN/AN/TNT -20/60/20 | – | – | – | – | – | – | – | – | BMT | 124 |
| EDDN/AN/RDX -35/35/30 | – | – | – | – | – | – | – | – | BMT | 132 |
| EDDN/TNT-45/55 | – | – | – | – | – | – | – | – | BMT | 109 |
| Ethylenediamine Diperchlorate | – | – | – | – | – | – | – | – | BMT | 135 |
| Ethylenediammonium-dinitroform | – | – | – | – | – | – | – | – | TT<br>BMT | 173<br>149 |
| Ethylenedinitramine (EDNA or Haleite) | – | – | – | ST<br>PDT<br>FET | 119<br>113-22<br>136-47 | –<br>1.5-1.6<br>1.50 | 7883 | 1.55 | TT<br>BMT | 124-43<br>136-40 |
| EDNA/Crown Oil-98/2 | – | – | – | FET | 133 | 1.50 | – | – | – | – |
| Ethyleneglycol Dinitrate | See Nitroglycol(NGc) | | | | | | | | | |
| Ethyl Nitrate | – | – | – | – | – | – | – | – | BMT | 123 |
| Ethyl Tetryl | See Trinitrophenylethylnitramine | | | | | | | | | |
| Ethyltrimethylol-methane Trinitrate | – | – | – | ST | 108-15 | – | – | – | BMT<br>TT | 127<br>132-46 |
| Explosive D | See Ammonium Picrate | | | | | | | | | |
| Fivolite(Tetramethyl-olcyclopentanol Penta-nitrate or Nitropentanol) | – | – | – | – | – | – | 7360 | 1.57 | BMT | 134 |
| Fivonite(FV)(Tetra-methylolcyclopentanone Tetranitrate or Nitro-pentanone) | – | – | – | PDT | 106-12 | 1.54 | 7300 | 1.57 | TT<br>BMT | 129<br>121-2 |

See page **B 266** for the meaning of Abbreviations

| Explosive | Brisance by Kast B ($\times 10^6$) | Relative %TNT | Density d g/cc | Brisance Method of Detg | Relative %TNT | Density d g/cc | Deton Velocity m/sec | Density d g/cc | Power Method of Detg | Relative %TNT |
|---|---|---|---|---|---|---|---|---|---|---|
| FV/EDNA-50/50 | See Ednafive | | | | | | | | | |
| FV/PETN-50/50 | See Pentafive | | | | | | | | | |
| FV/RDX-47/53 | See Cyclofive | | | | | | | | | |
| Galactan Trinitrate | – | – | – | ST | 88 | – | – | – | – | – |
| Gamsit(AN 60,NG 21, NGc 5,NC 1.6,liq DNT 12&woodmeal 0.4%) | Expl characteristics are similar to those of Telsit | | | | | | | | | |
| Gelatin Dynamite,65% (NG 62.5,NC 2.5,wood-meal 8.0 & $KClO_4$ 27.0%) | 112 | 130 | 1.66 | CCCT | 130 | 1.66 | 7000 | 1.66 | TT | 135-56 |
| Gelatin Dynamite,60% (NG 49.6,NC 1.2,Na nitrate 38.9,woodmeal 8.3,antacid 1.1&moisture 0.9%) | 96 | 112 | 1.6 | – | – | – | 6200 | 1.6 | BPT | 99 |
| Gelatin Dynamite 50% (NG 40.1,NC 0.8,Na nitrate 45.6,S 1.3,antacid 1.2 & moisture 1.2%) | – | – | – | PDT | 69 | 1.24 | 5600 | 1.5 | BPT | 90.5 |
| Gelatin Dynamite 40%(NG 32.0,NC 0.7,Na nitrate 51.7,S 2.2,antacid 1.2 & moisture 0.9%) | – | – | – | – | – | – | 5200 | – | BPT | 84.5 |
| Gelatin Pentrinit(NG 65, PETN 16.5,NC 4,AN 13.5 & DNT or TNT 1%) | – | – | – | – | – | – | 8000 | 1.65 | TT | 164 |
| Glycerol Dinitrate or Dinitroglycerin | – | – | – | LBCT | 135 | 1.51 | – | – | TT | 153 |
| Glcerol Monochlorohydrin Dinitrate or α-Dinitro-chlorohydrin | – | – | – | LBCT | 83 | 1.54 | – | – | TT | 135-53 |
| Glycerol Monolactate Trinitrate | – | – | – | – | – | – | – | – | BMT | 114 |
| Glycerol Trinitrate | See Nitroglycerin(NG) | | | | | | | | | |

See page **B 266** for the meaning of Abbreviations

| Explosive | Brisance by Kast B ($\times 10^6$) | Relative %TNT | Density d g/cc | Brisance Method of Detg | Relative %TNT | Density d g/cc | Deton Velocity m/sec | Density d g/cc | Power Method of Detg | Relative %TNT |
|---|---|---|---|---|---|---|---|---|---|---|
| Glycerol-$\alpha$(2,4,6-trinitrophenyl) Ether Dinitrate or Trinitril | – | – | – | Brisance is comparable to Tetryl | | | – | – | TT<br>BMT | 137-40<br>114 |
| Glycol Dinitrate | See Nitroglycol(NGc) | | | | | | | | | |
| Guanidine Perchlorate | – | – | – | – | – | – | 7150 | 1.67 | TT<br>BMT | 130<br>124 |
| Guanylnitrosaminoguanyltetrazene | See Tetracene | | | | | | | | | |
| Guanylurea Perchlorate | – | – | – | – | – | – | – | – | BMT | 92 |
| Guhr Dynamite (NG 75 & kieselguhr 25%) | 75.8 | 88 | 1.50 | CCCT | 86 | 1.50 | 6700 | 1.62 | TT | ca110 |
| Guncotton | See Nitrocellulose(N 13.2-13.4%) | | | | | | | | | |
| H-6(one of the HEX expls) | See Ref 30a,p 388(Conf) | | | | | | | | | |
| Haleite | See Ethylenedinitramine(EDNA) | | | | | | | | | |
| HEX's(High Blast Explosives)(US Navy) | Modifications of Torpex. Expl characteristics are given in Ref 30a,pp 382-7(Conf) | | | | | | | | | |
| HEX-1(RDX 39.6,TNT 37.8,Al 17.1,desensitizer D2 5.0&Ca chloride 0.5%) | – | – | – | PDT | 106 | 1.73 | 7400 | 1.69 | BMT | 133 |
| | (See also Ref 24b,p 45 & Ref 28,pp 198-9) | | | | | | | | | |
| Heptryl or 2,4,6-Trinitrophenyl-trimethylolmethylnitramine Trinitrate | – | – | – | – | – | – | – | – | BMT | 143 |
| | *Note:* Described as N(2,4,6-trinitro-N-anilino)-trimethylol Trinitrate in Vol 1,p A442-L | | | | | | | | | |
| HEX(High Energy Explosive) | See Ref 30a,pp 394-401(Conf) | | | | | | | | | |
| Hexamethylene-triperoxide-diamine(HMTPDA or HMTD) | – | – | – | ST | 99 | – | 5100 | 1.1 | TT | 60 |
| Hexamethylolbenzene Hexanitrate | – | – | – | – | – | – | – | – | BMT | 138 |
| Hexamine Diperchlorate | – | – | – | – | – | – | – | – | TT | ca130 |
| Hexamite(TNT 60, HNDPhA 24 & Al 16%) | – | – | – | ST | 116 | – | 6900 | 1.72 | TT<br>BMT | 116<br>130 |
| | Compare with Novit | | | | | | | | | |

See page **B 266** for the meaning of Abbreviations

| Explosive | Brisance by Kast B ($\times 10^6$) | Brisance Relative %TNT | Density d g/cc | Brisance Method of Detg | Brisance Relative %TNT | Density d g/cc | Deton Velocity m/sec | Density d g/cc | Power Method of Detg | Power Relative %TNT |
|---|---|---|---|---|---|---|---|---|---|---|
| Hexanit(Ger) | See Hexanitrodiphenylamine | | | | | | | | | |
| Hexanitroazobenzene | – | – | – | – | – | – | – | – | TT | 122 |
| | (See also Vol 1,p A649-R) | | | | | | | | | |
| Hexanitrobiphenyl | Some expl characteristics are given in this volume under Biphenyl and Derivatives | | | | | | | | | |
| Hexanitrodiphenylamine (HNDPhA or HNDP) | 111 | 129 | 1.67 | ST | 117-20 | – | 7400 | 1.64 | TT | 102-8 |
| | | | | CCCT | 114 | 1.64 | – | – | BMT | 111-15 |
| β-(Hexanitrodiphenyl-amino)-ethanol Nitrate | – | – | – | ST | 120 | 1.27 | – | – | TT | 134 |
| N,N'-(Hexanitrodiphenyl) -ethylenedinitramine | – | – | – | – | – | – | – | – | TT | 123 |
| | | | | | | | | | BMT | 123 |
| [Ditetryl (US),Octyl(Brit)] | Some expl characteristics are given in this vol under Bis(anilino)-ethane | | | | | | | | | |
| Hyman | See Nitromethylglycolamide Nitrate | | | | | | | | | |
| Inositol Hexanitrate | – | – | – | ST | 134 | – | – | – | – | – |
| Kresilit(Austrian) | See Trinitrocresol | | | | | | | | | |
| Lactose Octanitrate | – | – | – | ST | 134 | – | 4225 | 1.6 | – | – |
| Lead Azide(LA)(pure) | 74.9 | 87 | 3.8 | ST | 37-40 | – | 5300 | 4.6 | TT | 41-4 |
| | | | | FET | 17.4 | 4.83 | | | | |
| Lead Azide, dextrinated | – | – | – | ST | 35-8 | – | 5000 | 4.0 | TT | 38-43 |
| Lead Dinitroresorcinate (LDNR) | – | – | – | ST | 42 | – | – | – | | |
| LDNR, Basic | – | – | – | ST | 31 | – | – | – | | |
| Lead Styphnate(LSt) or | 63.7 | 74 | 2.6 | ST | 27-53 | – | 5200 | 2.9 | TT | 42 |
| Lead Trinitroresorcinate (LTNR) | 75 | 87 | 3.1 | | | | | | | |
| Liquid Oxygen Explosive (Carbon 27.3 & liqO 72.7%) | 45 | 52 | 0.8 | – | – | – | 4700 | 0.8 | – | – |
| Liquid Oxygen Explosive (Cuprene 24.8 & liqO 75.2%) | 113 | 132 | 1.06 | – | – | – | 5600 | 1.06 | – | – |

See page B 266 for the meaning of Abbreviations

| Explosive | Brisance by Kast B ($\times 10^6$) | Brisance Relative %TNT | Density d g/cc | Brisance Method of Detg | Brisance Relative %TNT | Density d g/cc | Deton Velocity m/sec | Density d g/cc | Power Method of Detg | Power Relative %TNT |
|---|---|---|---|---|---|---|---|---|---|---|
| Low Velocity Dynamite (LVD)[TNT 67.8, tripentaerythritol 8.6, cellulose acetate(LH-1) 2.0, RDX (Class E) 17.5 Vistac /DOS binder 4.1%] | – | – | – | ST | 84 | – | 4400 | 0.9 | – | – |
| | *Note*: RDX, Class E consists of RDX 99.5 & 1-MA dye 0.5%; 1-MA dye is 96% pure 1-methylamino-anthraquinone; Vistac/DOS binder consists of Vistac No 1 (low mw polybutene) 68 & DOS (dioctylsebacate) 32% | | | | | | | | | |
| Lyddite(Brit) | See Picric Acid | | | | | | | | | |
| Makarit or Macarite (TNT 30 & Pb nitrate 70%), also called Plumbatol | – | – | – | ST<br>CCCT | 68<br>90 | –<br>2.75 | 4850 | 2.89 | – | – |
| Maltose Octanitrate | – | – | – | ST | 113 | 1.62 | – | – | – | – |
| Hexanitrodiphenylsulfide (Dipicrylsulfide) | – | – | – | – | – | – | – | – | TT | 110 |
| Hexanitrodiphenylsulfone | – | – | – | – | – | – | – | – | TT | 115 |
| Hexanitrodiphenylurea | – | – | – | ST | 84 | – | – | – | BMT | 76 |
| Hexanitroethane | – | – | – | – | – | – | – | – | BMT | 108 |
| Hexanitroinositol | See Inositol Hexanitrate | | | | | | | | | |
| Hexanitromannitol | See Mannitol Hexanitrate | | | | | | | | | |
| Hexanitroöxanilide | – | – | – | ST | 134 | – | – | – | TT | 76 |
| Hexanitrosobenzene | – | – | – | – | – | – | – | – | TT<br>BMT | 156<br>147 |
| Hexil of Hexite | See Hexanitrodiphenylamine | | | | | | | | | |
| Hexogene | See Cyclotrimethylenetrinitramine | | | | | | | | | |
| Hexonit, 80/20 (RDX 80 & NG 20%) | Expl characteristics are similar to those of Pentrinit, 80/20 | | | | | | | | | |
| Hexotol(Swed) (RDX/TNT) | Expl characteristics are similar to those of Cyclotols | | | | | | | | | |
| Hexotonal(Swed) (RDX/TNT/Al) | Expl characteristics are similar to those of Torpex | | | | | | | | | |
| HMDT | See Hexamethylenetriperoxidediamine | | | | | | | | | |

See page B 266 for the meaning of Abbreviations

| Explosive | Brisance by Kast B ($\times 10^6$) | Brisance Relative %TNT | Density d g/cc | Brisance Method of Detg | Brisance Relative %TNT | Density d g/cc | Deton Velocity m/sec | Density d g/cc | Power Method of Detg | Power Relative %TNT |
|---|---|---|---|---|---|---|---|---|---|---|
| HMX (His Majesty's Explosive or High Melting Explosive) | See Cyclotetramethylenetetranitramine | | | | | | | | | |
| HNDP | See Hexanitrodiphenylamine | | | | | | | | | |
| Holtex | Swiss military expl of unknown compn; claimed to be very brisant and powerful | | | | | | | | | |
| HOX (High Oxygen Explosive) | Designation for Di(2,2,2-trinitroethyl)-nitramine, also called Bis(2,2,2-trinitroethyl)-nitramine (BTNEN) | | | | | | | | | |
| HTA (High Temperature, Aluminized) | See Ref 30a,pp 402-5(Conf) | | | | | | | | | |
| Hydrazine Nitrate | – | – | – | – | – | – | – | – | TT<br>BMT | 130-2<br>130 |
| Hydrazine Perchlorate | – | – | – | – | – | – | – | – | TT | 120 |
| Mannitol Hexanitrate or Hexanitromannitol | 174 | 201 | 1.7 | ST<br>PCT | 137-43<br>122-32 | –<br>1.7 | 8260 | 1.7 | TT<br>BMT | 172-96<br>136-50 |
| MeDINA | See Methylenedinitramine | | | | | | | | | |
| Medium Velocity Dynamite (MVD) (RDX 75, TNT 15, starch 5, SAE No 10 oil 4 & Vistanex oil gel 1%) | – | – | – | ST | 110 | 1.1 | – | – | – | – |
| | *Note*: Vistanex oil gel consists of SAE No 10 oil 80, Vistanex B-120XC 15 & Navy D2 wax 5% | | | | | | | | | |
| MeEDNA | See N-Methylethylenedinitramine | | | | | | | | | |
| Melinite (Fr & Rus) | See Picric Acid | | | | | | | | | |
| MeNENA | See 1-Nitroxytrimethylene-3-nitramine | | | | | | | | | |
| Mercuric Fulminate (MF) | 83.5 | 97 | 3.3 | ST | 49-55 | – | 5400 | 4.42 | TT | 51-54 |
| MF/$KClO_3$-90/10 | 74.1 | 86 | 3.1 | – | – | – | – | – | – | – |
| Methylamine Perchlorate | 143.1 | 167 | 1.3 | – | – | – | – | – | TT | 163 |
| Methylammonium Nitroform | – | – | – | – | – | – | – | – | TT | 185 |
| Methylenedinitramine (MeDINA) | – | – | – | ST | 127-31 | – | 8500 | 1.68 | TT<br>BMT | 188-210<br>154-8 |

See page **B 266** for the meaning of Abbreviations

| Explosive | Brisance by Kast B ($\times 10^6$) | Brisance Relative %TNT | Density d g/cc | Brisance Method of Detg | Brisance Relative %TNT | Density d g/cc | Deton Velocity m/sec | Density d g/cc | Power Method of Detg | Power Relative %TNT |
|---|---|---|---|---|---|---|---|---|---|---|
| N-Methylethylenedinitramine (MeEDNA) | – | – | – | – | – | – | – | – | BMT | 121 |
| α-Methylglycerol Trinitrate or 1,2,3-Butanetriol Trinitrate | – | – | – | ST | 113 | – | 7270 | 1.60 | BMT | 140 |
| β-Methylglycerol Trinitrate or 2-Methyl-1,2,3-propanetriol Trinitrate | – | – | – | ST | 112 | – | – | – | – | – |
| β-(N-Methylnitramino)-ethyl Nitrate | – | – | – | – | – | – | – | – | BMT | 137 |
| Methyl Nitrate | – | – | – | PCT<br>LBCT | 240<br>185 | 1.20<br>1.20 | 8000 | 1.20 | TT<br>BPD | 183-96<br>225 |
| Methylnitropropanediol Dinitrate | See Nitroisobutylglycol Dinitrate | | | | | | | | | |
| Methyl Tetryl | See Trinitromethylnitraminotoluene | | | | | | | | | |
| Methyltrimethylolmethane Trinitrate | See Metriol Trinitrate | | | | | | | | | |
| Metriol Trinitrate(MTN) or Pentaglycerin Trinitrate | – | – | – | ST<br>[See also PATR 2510(1958),p Ger 113] | 99 | 1.47 | – | – | TT<br>BMT | 150<br>134-6 |
| Minex(TNT 40,RDX 5-15, AN 25-35 & Al 20%) | This is one of the DBX's (See also Ref 28,p 198) | | | | | | | | | |
| Minol 2 (AN 40,TNT 40 & Al 20%) | – | – | – | ST<br>PDT | 95<br>62-66 | –<br>1.64-1.73 | 6000 | 1.70 | TT<br>BMT | 163<br>143 |
| MNO | See Dinitrodimethyloxamide | | | | | | | | | |
| Monochlorohydrin Dinitrate | See Glycerol Monochlorohydrin Dinitrate | | | | | | | | | |
| MOX (Metal Oxidizer Explosives) | See Ref 30a,p 406(Conf) | | | | | | | | | |
| MVD | See Medium Velocity Dynamite | | | | | | | | | |
| NENA or 1-Nitramino-2-ethanol Nitrate | See N-(β-Nitroxyethyl)-nitramine or Ethanolnitramine | | | | | | | | | |
| NENO | See Dinitrodi (β-nitroxyethyl)-oxamide | | | | | | | | | |

See page B 266 for the meaning of Abbreviations

| Explosive | Brisance by Kast B ($\times 10^6$) | Brisance Relative %TNT | Density d g/cc | Brisance Method of Detg | Brisance Relative %TNT | Density d g/cc | Deton Velocity m/sec | Density d g/cc | Power Method of Detg | Power Relative %TNT |
|---|---|---|---|---|---|---|---|---|---|---|
| Nitrocellulose(N ca 14%) | – | – | – | ST | 109-20 | 1.3 | – | – | – | – |
| Nitrocellulose(N 13.2 -13.4% (Guncotton) | 77 | 90 | 1.3 | ST<br>CCCT | 105<br>84 | –<br>1.3 | 7300 | 1.3 | TT<br>BMT | 136-47<br>118 |
| Nitrocellulose(N 12.6 -12.7%)(Pyrocotton) | – | – | – | ST | 94-98 | 1.3 | – | – | – | – |
| 2-Nitro-2-(3',5'-dinitro-phenyl)-propanediol -1,3-dinitrate | – | – | – | – | – | – | – | – | BMT | 126 |
| Nitroform | See Trinitromethane | | | | | | | | | |
| Nitrogen Dioxide/Nitro-benzene-70/30 | 139 | 162 | 1.38 | – | – | – | 8500 | 1.38 | – | – |
| Nitroglycerin(NG) | 145.9 | 170 | 1.6 | ST<br>LBCT | 120<br>115 | 1.6<br>1.6 | 7700 | 1.6 | TT<br>BMT | 185<br>140 |
| Nitroglycol(NGc) or Ethyleneglycoldi-nitrate(EGDN) | 158 | 184 | 1.50 | ST<br>LBCT | 129<br>115 | –<br>1.49 | 8000 | 1.49 | TT | 200-6 |
| Nitroguanidine(NGu) or Picrite | – | – | – | ST<br>LBCT<br>PDT | 81-4<br>73<br>95 | –<br>1.5<br>1.5 | 8100 | 1.70 | TT<br>BMT | 78-101<br>104 |
| Nitrohexanol | See Sixolite | | | | | | | | | |
| Nitrohexanone | See Sixonite | | | | | | | | | |
| Nitrohydrene(NG 80 & Nitrosugar 20%) | – | – | – | – | – | – | – | – | TT | 175 |
| Nitroisobutylglycerol Trinitrate (NIBGTN) | 168 | 195 | 1.68 | – | – | – | 7860 | 1.64 | TT | 200 |
| Nitroisobutylglycol Dinitrate(NIBGcDN) | – | – | – | ST | 113 | – | – | – | TT<br>BMT | 165<br>134-8 |
| Nitrolit(AN 40 & TNAns 60%) | Expl characteristics similar to those of Amatol, 40/60(Ref 24,p 110-11) | | | | | | | | | |
| Nitromannite | See Mannitol Hexanitrate | | | | | | | | | |
| Nitromethane | – | – | – | – | – | – | 6210 | 1.13 | TT<br>BMT | 138-43<br>133-4 |

See page B 266 for the meaning of Abbreviations

| Explosive | Brisance by Kast B ($\times 10^6$) | Relative %TNT | Density d g/cc | Brisance Method of Detg | Relative %TNT | Density d g/cc | Deton Velocity m/sec | Density d g/cc | Power Method of Detg | Relative %TNT |
|---|---|---|---|---|---|---|---|---|---|---|
| Nitromethylglycolamine Nitrate (Hyman) | – | – | – | – | – | – | 7420 | 1.5 | BMT | 133 |
| N-Nitro-N-methyl-hydroxyacetamide Nitrate | – | – | – | – | – | – | 7420 | 1.50 | BMT | 132 |
| 2-Nitro-2-(m-nitrophenyl) -propanediol-1,2-dinitrate | – | – | – | – | – | – | – | – | BMT | 114 |
| Nitropenta or Nitro-pentaerythrite | See Pentaerythritol Tetranitrate | | | | | | | | | |
| m-Nitrophenyl-dinitromethane | – | – | – | – | – | – | – | – | BMT | 100 |
| Nitrophenylnitromethyl-carbinol Nitrate | – | – | – | – | – | – | – | – | BMT | 99 |
| Nitropicramide | See Trinitrophenylnitramine | | | | | | | | | |
| Nitrosorbitan Tetra-nitrate | – | – | – | – | – | – | – | – | BMT | 133 |
| Nitrostarch(NS) (13.35-13.45% N) | – | – | – | CCCT | 83 | 0.9 | 6190 | 0.9 | TT<br>BMT | 145<br>120 |
| Nitrostarch(NS)(12.8%N) | – | – | – | CCCT | 75 | 0.9 | 5300 | 0.9 | TT<br>BMT | 127<br>114 |
| Nitrostarch(NS)(12.12%N) | – | – | – | CCCT | 46 | 0.9 | 4480 | 0.9 | TT | 108 |
| Nitrostarch Demolition Explosive(NSX)[NS(12.5% N)49,Ba nitrate 40,MNN 7, p-MNA 3 & oil 1%] | – | – | – | ST | 82 | – | – | – | – | – |
| | (See also Trojan Explosive) (Compare with Demolition Explosive, described in Ref 28,p 207) | | | | | | | | | |
| Nitrosucrose | See Sucrose Octanitrate | | | | | | | | | |
| Nitrotetryl | See Tetranitrophenylmethylnitramine | | | | | | | | | |
| Nitrourea | – | – | – | ST | 60 | – | – | – | BMT | 105 |
| N-(β-Nitroxyethyl) -nitramine(NENA); 1-Nitramino-2-ethanol Nitrate or Ethanolnitramine Nitrate | – | – | – | – | – | – | – | – | BMT | 134-48 |

See page B 266 for the meaning of Abbreviations

| Explosive | Brisance by Kast B ($\times 10^6$) | Relative %TNT | Density d g/cc | Brisance Method of Detg | Relative %TNT | Density d g/cc | Deton Velocity m/sec | Density d g/cc | Power Method of Detg | Relative %TNT |
|---|---|---|---|---|---|---|---|---|---|---|
| 1-Nitroxytrimethylene-3-nitramine (Me NENA) | – | – | – | – | – | – | – | – | BMT | 136 |
| Novit, 60/40 (TNT 60 & HNDPhA 40%) (Swedish) | – | – | – | ST | 105 | – | 7000 | 1.5 | TT | 105 |
| | (Compare with Hexamit, described in PATR 2510 (1958), p Ger 88) | | | | | | | | BMT | 106-9 |
| NP (Ger) | Same as PETN | | | | | | | | | |
| Nyperit (Ger) | Same as PETN | | | | | | | | | |
| Octol, 77/23 (HMX 77 & TNT 23) | Expl characteristics of Octol 77/23 are given in Ref 31, pp 814-15 and for Octols 70/30 & 75/25 in Ref 30a, pp 424-33 (Conf) | | | | | | | | | |
| Octyl (Brit) or Ditetryl (US) | See N-N'-(Hexanitrodiphenyl)-ethylenedinitramine | | | | | | | | | |
| Oxytetryl | See Trinitromethylnitraminophenol | | | | | | | | | |
| PA | See Picric Acid | | | | | | | | | |
| Parazol | See Dinitrodichlorobenzene | | | | | | | | | |
| PB-RDX (Plastic Bonded RDX) | See Ref 30a, p 434 (Conf) | | | | | | | | | |
| PE-1 (Brit plastic expl) (RDX 88.3 & special PE oil 11.7%) | See Ref 24b, pp 28-9. It was replaced by PE-2 | | | | | | | | | |
| PE-2 (Brit) | Same as Composition C (See also Ref 24b, p 29) | | | | | | | | | |
| Pentaerythritol Tetranitrate (PETN) or Penthrite | 172.8 | 200 | 1.69 | ST | 129-41 | – | 8300 | 1.70 | TT | 161-81 |
| | 183.7 | 214 | 1.69 | LBCT | 130-7 | 1.4-1.5 | | | BMT | 137-45 |
| | 193 | 225 | 1.7 | PDT | 127 | 1.5-1.6 | | | | |
| PETN/Aristowax-95/5 | – | – | – | FET | 147 | 1.65 | | | | |
| PETN/Pentowax-87/13 | – | – | – | FET | 139 | 1.61 | | | | |
| PETN/Aristowax-80/20 | – | – | – | FET | 124 | 1.54 | | | | |
| Pentaerthritol Trinitrate (PETRIN) and PETRIN Acrylate | Some expl characteristics are given in Ref 30a, pp 440-9 (Conf) | | | | | | | | | |
| Pentamethylenetetramine Dinitrate | – | – | – | – | – | – | – | – | TT | ca 180 |
| Pentanitroaniline (PNA) | – | – | – | – | – | – | – | – | TT | 159-79 |
| | | | | | | | | | BMT | 142 |

See page B 266 for the meaning of Abbreviations

| Explosive | Brisance by Kast B ($\times 10^6$) | Brisance Relative %TNT | Density d g/cc | Brisance Method of Detg | Brisance Relative %TNT | Density d g/cc | Deton Velocity m/sec | Density d g/cc | Power Method of Detg | Power Relative %TNT |
|---|---|---|---|---|---|---|---|---|---|---|
| Pentanitrophenylmethyl-nitramine | – | – | – | – | – | – | – | – | TT | 152 |
| Pentastit,93/7(PETN 93&PE-tetrastearate 7%) (Swiss) | – | – | – | CCCT | 122 | 1.56 | 8000 | 1.56 | TT | 140 |
| Pentastit,93/7 with 20% Al | – | – | – | CCCT | 116 | 1.68 | 7700 | 1.68 | TT | 161 |
| Pentastit,96.5/3.5(PETN 96.5&PE-tetrastearate 3.5%) | – | – | – | CCCT | 127 | 1.60 | 8100 | 1.60 | TT | 144 |
| Pentastit,96.5/3.5 with 20% Al | – | – | – | CCCT | 117 | 1.67 | 7700 | 1.67 | TT | 176 |
| Pentol(Ger) | See Pentolite | | | | | | | | | |
| Pentolite, 75/25(PETN 75 & TNT 25%) | *Note*: Stettbacher used the term "Pentryl" to designate mixts PETN + TNT | | | | | | | | | |
| Pentolite,70/30 (PETN70 & TNT30%) | – | – | – | ST<br>CCCT | 131<br>121 | –<br>1.58 | 7800 | 1.58 | TT | 136 |
| Pentolite , 70/30 with 15% Al | – | – | – | CCCT | 122 | 1.65 | 7400 | 1.65 | TT | 171 |
| Pentolite,60/40(PETN 60 & TNT 40%) | – | – | – | ST<br>PDT<br>CCCT | 127<br>113<br>118 | –<br>1.6<br>1.56 | 7620 | 1.66 | TT<br>BMT | 127<br>127 |
| Pentolite,60/40 with 15% Al | – | – | – | CCCT | 117 | 1.68 | 7200 | 1.68 | TT | 168 |
| Pentolite,50/50(PETN 50 & TNT 50%) | – | – | – | ST<br>PDT<br>FET<br>CCCT | 123<br>111<br>131<br>113 | –<br>1.6<br>1.65<br>1.55 | 7510 | 1.66 | TT<br>BMT | 121<br>122 |
| Pentolite,50/50 with 15% Al | – | – | – | CCCT | 117 | 1.62 | 7000 | 1.62 | TT<br>BMT | 155<br>126 |
| Pentolite,40/60(PETN 40 & TNT 60%) | – | – | – | ST | 118 | – | 7370 | 1.65 | BMT | 118 |
| Pentolite,30/70(PETN 30 & TNT 70%) | – | – | – | ST | 113 | – | – | – | – | – |

See page **B 266** for the meaning of Abbreviations

| Explosive | Brisance by Kast B ($\times 10^6$) | Relative %TNT | Density d g/cc | Brisance Method of Detg | Relative %TNT | Density d g/cc | Deton Velocity m/sec | Density d g/cc | Power Method of Detg | Relative %TNT |
|---|---|---|---|---|---|---|---|---|---|---|
| Pentolite ,25/75(PETN 25 & TNT 75%) | – | – | – | ST | 111 | – | 7150 | 1.62 | BMT | 111 |
| Pentolite, 10/90(PETN 10 & TNT 90%) | – | – | – | ST | 105 | – | – | – | – | – |
| Pentonal,47/33/20 (PETN 47, TNT 33 & Al 20%) | Expl characteristics not found; it was, however, stated that it is very sensitive to bullet impact(Ref 24b,p 33) | | | | | | | | | |
| Pentrinit,80/20(PETN 80 & NG 20%)(Swiss) | 178 | 208 | 1.72 | – | – | – | 8400 | 1.72 | TT | 179 |
| Pentrinit,50/50 (PETN 50 & NG 50%) | – | – | – | – | – | – | 8000 | 1.65 | – | – |
| Pentrinit,50/50 with 30% Al | – | – | – | – | – | – | 7200 | 1.9 | – | – |
| Pentritol(Ger) | See Pentolite | | | | | | | | | |
| Pentryl | Stettbacher's name for mixts of PETN and TNT, called Pentolite in the US | | | | | | | | | |
| Pentryl or Trinitro-nitranilinoethanol Nitrate | – | – | – | ST<br>LBCT<br>PCT<br>FET | 129<br>125<br>117<br>>110 | –<br>1.6<br>– | 7340 | 1.65 | TT<br>BMT | 130<br>124-33 |
| PEP-2(PETN 85 & Gulf Crown Oil E 15%) | – | – | – | – | – | – | – | – | BMT | 115 |
| | (See also Ref 24b,p 30) | | | | | | | | | |
| PEP-3(PETN 86 & Gulf Crown Oil E 14%) | – | – | – | ST<br>PDT<br>FET | 106<br>100<br>124 | –<br>1.50<br>1.51 | 7778 | 1.47 | BMT | 115 |
| PETN | See Pentaerythritol Tetranitrate | | | | | | | | | |
| PETRIN | See Pentaerythritol Trinitrate | | | | | | | | | |
| PETX | See Tetra(nitraminomethyl)-methane | | | | | | | | | |
| Picramide | See Trinitroaniline | | | | | | | | | |
| Picratol,52/48(Amm picrate 52 & TNT 48%) | – | – | – | ST<br>PDT<br>FET | 94<br>100<br>102 | –<br>1.63<br>1.61 | 6970 | 1.67 | BMT | 100 |
| | *Note*: It is called Picrotol in Ref 24b,p 32 | | | | | | | | | |

See page B 266 for the meaning of Abbreviations

| Explosive | Brisance by Kast B ($\times 10^6$) | Brisance Relative %TNT | Density d g/cc | Brisance Method of Detg | Brisance Relative %TNT | Density d g/cc | Deton Velocity m/sec | Density d g/cc | Power Method of Detg | Power Relative %TNT |
|---|---|---|---|---|---|---|---|---|---|---|
| Picric Acid(PA) or Trinitrophenol | 107.4<br>118.1 | 125<br>137 | 1.69<br>1.63 | ST<br>CCCT<br>PDT<br>FET | 103-10<br>114-23<br>107<br>122 | –<br>1.6-1.69<br>1.6<br>1.70 | 7460 | 1.70 | TT<br>BMT | 103-17<br>106-12 |
| Picrite | See Nitroguanidine | | | | | | | | | |
| Picrotol | Same as Picratol | | | | | | | | | |
| Picryl Azide | – | – | – | – | – | – | – | – | BMT | 139 |
| Picryl Chloride(Trinitrochlorobenzene) | – | – | – | CCCT | 114 | – | 7130 | 1.75 | TT | 103-10 |
| Picrylnitramine | See Trinitrophenylnitramine | | | | | | | | | |
| PIPE(PETN 81 & Gulf Crown Oil E 19%) | – | – | – | ST<br>PDT<br>FET | 87-94<br>76<br>79 | –<br>1.33<br>1.36 | 7075 | 1.37 | TT | 106 |
| Plumbatol | See Macarite | | | | | | | | | |
| PLX,90/5(Nitromethane 95 & ethylenediamine 5%) | – | – | – | ST | 105 | 1.12 | 6165 | 1.12 | – | – |
| Polyvinyl Nitrate(PVN) | – | – | – | ST | 104-7 | – | – | – | – | – |
| Potassium Dinitrobenzofuroxan(KDNBF) | – | – | – | ST | 93 | 2.2 | – | – | – | – |
| Propanediol Dinitrate | See Trimethyleneglycol Dinitrate | | | | | | | | | |
| Propargyl Picrate | – | – | – | – | – | – | – | – | TT<br>BMT | 95<br>99 |
| Propylenedinitramine(PDNA) | See Trimethylenedinitramine | | | | | | | | | |
| Propyleneglycol Dinitrate | – | – | – | – | – | – | – | – | TT | 155 |
| PTX-1(RDX 30, Tetryl 50 & TNT 20%) | – | – | – | ST<br>PDT<br>FET | 119-22<br>127<br>135-7 | –<br>1.68<br>1.68 | 8000 | 1.68 | BMT | 132 |
| PTX-2(RDX 43.2, PETN 28 & TNT 28.8%) | – | – | – | ST<br>PDT<br>FET | 125-7<br>141<br>153 | –<br>1.71<br>1.68 | 8065 | 1.70 | BMT | 138-45 |

See page **B 266** for the meaning of Abbreviations

| Explosive | Brisance by Kast B ($\times 10^6$) | Brisance Relative %TNT | Density d g/cc | Brisance Method of Detg | Brisance Relative %TNT | Density d g/cc | Deton Velocity m/sec | Density d g/cc | Power Method of Detg | Power Relative %TNT |
|---|---|---|---|---|---|---|---|---|---|---|
| PVA-4(Polyvinyl acetate 6-8,RDX 92-90 & dibutyl-phthalate 2) | – | – | – | ST | 122 | – | 7910 | 1.60 | – | – |
| PVN | See Polyvinyl Nitrate | | | | | | | | | |
| RDX(Research Department Explosive) | See Cyclotrimethylenetrinitramine | | | | | | | | | |
| RDX Polar PE(RDX 88 & 95/5 mixt of Gulf 300 Process Oil/Lecithin 12%) | Expl characteristics similar to Composition C (See also Ref 24b,p 29) | | | | | | | | | |
| RIPE(RDX 85 & Gulf Crown Oil E 15%) | – | – | – | ST<br>FET<br>PDT | 84-91<br>89<br>85 | –<br>1.39<br>1.37 | 7390<br>–<br>– | 1.37<br>–<br>– | BMT<br>–<br>– | 118<br>–<br>– |
| Shellite(Brit) | See Tridite,70/30 | | | | | | | | | |
| Shimose(Jap) | See Picric Acid | | | | | | | | | |
| Silver Acetylide | 94 | 109 | 4.0 | – | – | – | – | – | – | – |
| Silver Azide | – | – | – | ST<br>FET | 40-3<br>66 | –<br>4.97 | – | – | – | – |
| Sixolite(Tetramethylolcyclohexanol Pentanitrate or Nitrohexanol) | – | – | – | – | – | – | 7430 | 1.58 | TT<br>BMT | 135<br>127 |
| Sixonite(Tetramethylolcyclohexanone Tetranitrate or Nitrohexanone) | – | – | – | – | – | – | 7740 | 1.51 | BMT | 114 |
| Styphnic Acid | See Trinitroresorcinol | | | | | | | | | |
| Sucrose Octanitrate | – | – | – | – | – | – | – | – | TT | 102 |
| Telsit(Swiss) (AN 55.5,NG 22,NC 1.5 & liq DNT with TNT 21%) | – (Ref 10,p 242) | – | – | LBCT | 93 | 1.55 | 6000 | 1.55 | TT | 129 |
| Tetracene or Guanylnitrosaminoguanyltetrazene | – | – | – | ST | 40-70 | – | – | – | TT | 51-63 |
| Tetramethylolcyclohexanol Pentanitrate | See Sixolite | | | | | | | | | |

See page B 266 for the meaning of Abbreviations

| Explosive | Brisance by Kast B ($\times 10^6$) | Brisance Relative %TNT | Density d g/cc | Brisance Method of Detg | Brisance Relative %TNT | Density d g/cc | Deton Velocity m/sec | Density d g/cc | Power Method of Detg | Power Relative %TNT |
|---|---|---|---|---|---|---|---|---|---|---|
| Tetramethylolcyclohexanone Tetranitrate | See Sixonite | | | | | | | | | |
| Tetramethylolcyclopentanol Tetranitrate | See Fivolite | | | | | | | | | |
| Tetramethylolcyclopentanone Tetranitrate | See Fivonite | | | | | | | | | |
| Tetra(nitraminomethyl)-methane, designated PETX | – | – | – | – | – | – | – | – | BMT | 129 |
| Tetranitroaniline(TeNA) | – | – | – | ST | 102 | – | 7630 | 1.6 | TT | 130-49 |
| | *Note*: According to some investigators TeNA is more brisant than Tetryl (See also Vol 1,p A411-R) | | | | | | | | BMT | 121 |
| | | | | | | | | | BPT | 146 |
| Tetranitroanisole(TeNAns) (TeNAns) | – | – | – | – | – | – | – | – | TT | 131-8 |
| | (See also Vol 1,p A454-R) | | | | | | | | | |
| Tetranitrobenzene(TeNB) | – | – | – | – | – | – | – | – | TT | 150 |
| | (See also Vol 2,under Benzene) | | | | | | | | | |
| Tetranitrobutane (TeNBu) | – | – | – | – | – | – | – | – | TT | 176-9 |
| | (See also Vol 2, under Butane) | | | | | | | | BMT | 146-53 |
| Tetranitrocarbazole (TeNCbz) | | – | – | ST | 86-95 | – | – | – | – | – |
| Tetranitrodiglycerin (TeNDG) | – | – | – | ST | 108 | – | – | – | TT | 150-9 |
| Tetranitromethane | – | – | – | ST | 108 | – | 6400 | 1.65 | TT | 54 |
| Tetranitromethane/ Nitrobenzene-77.2/22.5 | – | – | – | – | – | – | 7700 | 1.5 | – | – |
| Tetranitromethane/ Toluene-86.5/13.5 | 212 | 246 | 1.45 | – | – | – | – | – | – | – |
| Tetranitromethylaniline | See Tetryl | | | | | | | | | |
| Tetranitronaphthalene (TeNN) | – | – | – | – | – | – | – | – | BMT | 101 |
| Tetranitroöxanilide (TeNOx) | – | – | – | ST | 34 | – | – | – | – | – |
| Tetranitrophenyl-methylnitramine or m-Nitrotetryl | – | – | – | – | – | – | – | – | TT | 154-6 |
| | | | | | | | | | BMT | 134-41 |

See page B 266 for the meaning of Abbreviations

| Explosive | Brisance by Kast B ($\times 10^6$) | Brisance Relative %TNT | Density d g/cc | Brisance Method of Detg | Brisance Relative %TNT | Density d g/cc | Deton Velocity m/sec | Density d g/cc | Power Method of Detg | Power Relative %TNT |
|---|---|---|---|---|---|---|---|---|---|---|
| Tetranitrotoluene(TeNT) | – | – | – | – | – | – | – | – | TT | 127 |
| Tetra($\beta$-nitroxyethyl) -ammonium Nitrate | – | – | – | – | – | – | >8000 | 1.6 | TT<br>BMT | 156-8<br>138-41 |
| Tetratetryl | See Tetra(2,4,6-trinitrophenylnitraminonethyl)-methane | | | | | | | | | |
| Tetratol | See Tetrytol | | | | | | | | | |
| Tetra(2,4,6-trinitro-phenylnitraminomethyl) -methane or Tetratetryl | – | – | – | – | – | – | – | – | TT | 132 |
| Tetroxyl | See Trinitrophenylmethoxynitramine | | | | | | | | | |
| Tetryl(US) or CE(Brit) (Trinitrophenylmethyl-nitramine or Trinitro -N-methylnitramine) | 114.9 | 134 | 1.63 | ST<br>CCCT<br>LBCT<br>PDT<br>FET | 113-23<br>117-25<br>112<br>115<br>121 | –<br>1.59-1.63<br>–<br>1.59<br>1.60 | 7850 | 1.71 | TT<br>BMT<br>BPT | 125-45<br>126-32<br>145 |
| Tetrytol,80/20 (Tetryl 80 & TNT 20%) | – | – | – | ST | 122 | – | 7425 | 1.64 | BMT | 123 |
| Tetrytol,75/25 (Tetryl 75 & TNT 25%) | – | – | – | ST<br>PDT<br>FET | 120<br>114-19<br>120 | –<br>1.62-1.66<br>1.60 | 7390 | 1.62 | BMT | 122 |
| Tetrytol,70/30 (Tetryl 70 & TNT 30%) | – | – | – | ST<br>PDT<br>FET | 119<br>117<br>119 | –<br>1.60<br>1.60 | 7350 | 1.61 | BMT<br>TT | 120<br>120 |
| Tetrytol,65/35(Tetryl 65 & TNT 35%) | – | – | – | ST<br>FET | 118<br>118 | –<br>1.60 | 7310 | 1.60 | BMT | 119 |
| Tetrytol,40/60(Tetryl 40 & TNT 60%) | – | – | – | ST<br>FET | 113<br>113 | –<br>1.60 | 7120 | 1.62 | BMT | 112 |
| | *Note*: Tetrytols are listed in Ref 18a as Tetratols | | | | | | | | | |
| TNA | See Trinitroaniline | | | | | | | | | |
| TNAns | See Trinitroanisole | | | | | | | | | |
| TNB | See Trinitrobenzene | | | | | | | | | |
| TNN | See Trinitronaphthalene | | | | | | | | | |
| TNT | See Trinitrotoluene | | | | | | | | | |
| Tol or Tolite | See Trinitrotoluene | | | | | | | | | |

See page B 266 for the meaning of Abbreviations

| Explosive | Brisance by Kast B ($\times 10^6$) | Brisance Relative %TNT | Density d g/cc | Brisance Method of Detg | Brisance Relative %TNT | Density d g/cc | Deton Velocity m/sec | Density d g/cc | Power Method of Detg | Power Relative %TNT |
|---|---|---|---|---|---|---|---|---|---|---|
| Torpex(RDX 45,TNT 37 & Al 18%) | – | – | – | ST<br>FET<br>PDT | 122<br>126<br>120 | –<br>1.75<br>– | 7495 | 1.8 | TT<br>BMT | 161-2<br>132-50 |
| Torpex-2(RDX 42,TNT 40 & Al 18%) | – | – | – | ST<br>PDT<br>FET | 132-60<br>116-19<br>126 | –<br>1.80<br>1.77 | 7660<br>(Refs 24 & 24b) | 1.80 | TT<br>BMT | 140-66<br>134-64 |
| Triaminotrinitrobenzene | See Ref 30a,p 454(Conf) | | | | | | | | | |
| Triazidotrinitrobenzene (TATNB) | – | – | – | PPT | 1.58 | 1.75 | – | – | TT<br>BMT | 165-71<br>147 |
| Tricycloacetone Peroxide | – | – | – | ST | 80 | – | 5300 | 1.18 | – | – |
| Tridite,70/30(US); Shellite(Brit)(PA 70 & HNDPhA 30%) | – | – | – | ST | 89 | – | 6600 | 1.6 | TT<br>BMT | 95<br>91 |
| Tridite,60/40(PA 60 & HNDPhA 40%) | – | – | – | ST | 84 | – | 6300 | 1.6 | TT<br>BMT | 92<br>90 |
| Tridite,90/10(PA 90 & HNDPhA 10%) | – | – | – | ST<br>(Ref 24,p 57, table) | 100 | – | 7000 | 1.6 | TT<br>BMT | 102<br>100 |
| Triethyleneglycol Dinitrate(TEGDN) | – | – | – | ST | 31 | 1.32 | – | – | – | – |
| Trimethylenedinitramine or Propylenedinitramine (PDNA) | – | – | – | – | – | – | – | – | BMT | 116 |
| Trimethyleneglycol-Dinitrate(TMGcDN) or Propanediol Dinitrate | – | – | – | – | – | – | 6890 | 1.39 | TT | 80-90NG |
| Trimethylolethane Trinitrate or Nitro-pentaglycerin | See Metriol Trinitrate | | | | | | | | | |
| Trimethylolnitro-methane Trinitrate | See Nitroisobutylglycerin Trinitrate | | | | | | | | | |
| Trimethylolpropane Trinitrate or Ethyl-trimethylolmethane Trinitrate(EMMET) | – | – | – | ST | 108-15 | – | – | – | TT<br>BMT | 132-46<br>127 |

See page B 266 for the meaning of Abbreviations

| Explosive | Brisance by Kast B ($\times 10^6$) | Brisance Relative %TNT | Density d g/cc | Brisance Method of Detg | Brisance Relative %TNT | Density d g/cc | Deton Velocity m/sec | Density d g/cc | Power Method of Detg | Power Relative %TNT |
|---|---|---|---|---|---|---|---|---|---|---|
| Trilite | See Trinitrotoluene | | | | | | | | | |
| Trimonite,90/10 (PA90&MNT 10%) | – | – | – | ST | 92-7 | – | 7080 | 1.60 | TT<br>BMT | 94<br>95 |
| 1,1,1-Trinitraminomethyl-methane | – | – | – | – | – | – | – | – | BMT | 112 |
| Trinitroaniline (TNA) or Picramide | – | – | – | – | – | – | 7600 | 1.7 | TT | 107 |
| | (See also Vol 1,p A410) | | | | | | | | | |
| Trinitroanisole (TNAns) | 87.1 | 101 | 1.59 | ST<br>CCCT | 100-10<br>92-100 | –<br>1.59 | 7000<br>– | 1.59<br>– | TT<br>BMT | 104-8<br>106-8 |
| | (See also Vol 1,p A451-L) | | | | | | | | | |
| Trinitrobenzaldehyde (TNBA) | – | – | – | ST | 117 | – | – | – | TT | ca 100 |
| | (See also Vol 2, under Benzaldehyde) | | | | | | | | | |
| Trinitrobenzene (TNB) | 105<br>110.3 | 122<br>129 | 1.63<br>1.63 | ST<br>CCCT<br>LBCT<br>FET | 110<br>114<br>111<br>117 | –<br>1.63<br>1.6<br>1.7 | 7350 | 1.66 | TT<br>BMT | 105-20<br>105-17 |
| | (See also Vol 2,under Benzene) | | | | | | | | | |
| Trinitrobenzoic Acid | – | – | – | ST | 100 | – | – | – | BMT | 98 |
| | (See also Vol 2,under Benzoic Acid) | | | | | | | | | |
| Trinitrobenzyl Nitrate | – | – | – | – | – | – | – | – | BMT | 126-7 |
| | (See also Vol 2,under Benzyl Alcohol and Derivatives) | | | | | | | | | |
| Trinitro-bis(methyl-nitramino-benzene) | See Trinitrodi(methylnitramino)-benzene (Ditetryl) | | | | | | | | | |
| Trinitrochlorobenzene (TNClB) | 106.5 | 124 | 1.74 | CCCT | 97 | 1.62 | – | – | – | – |
| Trinitrocresol(TNCrs) or Cresylite | 84.3 | 98 | 1.62 | CCCT | 97-105 | 1.62 | 6850 | 1.62 | TT<br>BMT | 86-99<br>94 |
| Trinitro-di(methyl-nitramino)-benzene; Ditetryl(Brit) | – | – | – | – | – | – | – | – | TT<br>BMT | 130<br>123 |
| Trinitroethanol | – | – | – | – | – | – | – | – | TT | 161-2 |
| Trinitroethylamino-tetrazole | – | – | – | – | – | – | – | – | TT | 161 |

See page **B 266** for the meaning of Abbreviations

| Explosive | Brisance by Kast B ($\times 10^6$) | Brisance Relative %TNT | Density d g/cc | Brisance Method of Detg | Brisance Relative %TNT | Density d g/cc | Deton Velocity m/sec | Density d g/cc | Power Method of Detg | Power Relative %TNT |
|---|---|---|---|---|---|---|---|---|---|---|
| Trinitroethylbenzene (TNEB) | – | – | – | ST | 88 | – | – | – | – | – |
| Trinitroethyltrinitro-butyrate | See Ref 30a,p 459(Conf) | | | | | | | | | |
| Trinitromelamine | – | – | – | – | – | – | – | – | BMT | 101 |
| Trinitromesitylene | – | – | – | – | – | – | – | – | BMT | 84 |
| Trinitromethane or Nitroform | – | – | – | – | – | – | – | – | TT<br>BMT | ca 100<br>125 |
| 2,2,3-Trinitro-3-methylbutane | – | – | – | – | – | – | – | – | BMT | 104 |
| Trinitromethyl-nitraminotoluene or Methyltetryl | – | – | – | – | – | – | – | – | TT<br>BMT | 112<br>110 |
| Trinitronaphthalene (TNN) | – | – | – | – | – | – | – | – | BMT | 83 |
| Trinitrophenetole | – | – | – | – | – | – | 6880 | cast | TT<br>BMT | 84<br>80 |
| Trinitrophenol | See Picric Acid | | | | | | | | | |
| Trinitrophenoxy-ethyl Nitrate | – | – | – | PCT | 90 | – | – | – | TT | 122 |
| 1-(2,4,6-Trinitro-phenoxy)-propane-2,3-diol | – | – | – | – | – | – | – | – | BMT | 120 |
| Trinitrophenyl Azide or Picryl Azide | – | – | – | PCT | 117-32 | – | – | – | TT | 135-9 |
| Trinitrophenylbutyl-nitramine or Butyl-tetryl | – | – | – | ST | 100 | – | – | – | BMT | 97-8 |
| Trinitrophenylethyl-nitramine or Ethyl-tetryl | – | – | – | – | – | – | 6200 | 1.6 | TT<br>BMT | 114<br>111 |
| Trinitrophenylmethoxy-nitramine | – | – | – | – | – | – | – | – | TT | 142 |

See page B 266 for the meaning of Abbreviations

| Explosive | Brisance by Kast B ($\times 10^6$) | Brisance Relative %TNT | Density d g/cc | Brisance Method of Detg | Brisance Relative %TNT | Density d g/cc | Deton Velocity m/sec | Density d g/cc | Power Method of Detg | Power Relative %TNT |
|---|---|---|---|---|---|---|---|---|---|---|
| Trinitrophenylmethyl-nitramine | See Tetryl | | | | | | | | | |
| 2,4,6-Trinitrophenyl--(1-methylol)-propyl-nitramine Nitrate | – | – | – | – | – | – | – | – | BMT | 117 |
| Trinitrophenylnitramine; Nitropicrylamide or Picrylnitramine | – | – | – | – | – | – | – | – | TT | ca 150 |
| Trinitro phenylnitramino-ethyl Nitrate | See Pentryl | | | | | | | | | |
| Trinitrophenyltri-methylolmethyl-nitramine Trinitrate | See Heptryl | | | | | | | | | |
| Trinitroresorcinol (TNR) or Styphnic Acid | – | – | – | ST | 94 | – | – | – | TT<br>BMT | 105-15<br>108 |
| Trinitrosotrimethylene-triamine | – | – | – | – | – | – | – | – | BMT | 134 |
| Trinitrotoluene(TNT); Tolite; Tol; Trotyl; Triton; Tritolo | 86.1 | 100 | 1.59 | ST<br>ST | 100<br>ca80% of PETN or RDX | –<br>– | 6970 | 1.59<br>(cast) | TT<br>TT | 100<br>90-95%PA |
| | | | (Sand crushed by 0.4g TNT= 43-48g) | | | | | | (Lead block expans caused by 10g TNT 285-305cc) | |
| | | | | CCCT | 100 | 1.59 | | | BMT | 100 |
| | | | (Compression of Cu cylinder ca 3.5mm) | | | | | | | |
| | | | | LBCT | 100 | 1.59 | | | BMT | 89%PA |
| | | | (Compression of Pb cylinder ca 16mm) | | | | | | | |
| | | | | PDT | 100 | 1.59 | | | BMT | 65.5% of Blasting Gelatin |
| | | | (Depth of dent in the plate ca 0.205mm) | | | | | | | |
| | | | | FET | 100 | 1.59 | | | | |
| | | | (Number of fragments in 90mm shell ca 703 and in 3" shell ca 514) | | | | | | | |
| TNT+ 0.05-0.10% Span 85 | – | – | – | FET | 97 | 1.59 | – | – | – | – |
| TNT/D2-95/5 | – | – | – | FET | 93 | 1.75 | — | – | – | – |
| Trinitrotriazidobenzene | See Triazidotrinitrobenzene | | | | | | | | | |
| Trinitroxylene(TNX) | – | – | – | ST | 84 | – | 6600 | 1.51 | TT | 93 |
| Tripentaerythritol Octanitrate | See Ref 30a,p 465(Conf) | | | | | | | | | |

See page B 266 for the meaning of Abbreviations

| Explosive | Brisance by Kast B ($\times 10^6$) | Brisance Relative %TNT | Brisance Density d g/cc | Brisance Method of Detg | Brisance Relative %TNT | Brisance Density d g/cc | Deton Velocity m/sec | Power Density d g/cc | Power Method of Detg | Power Relative %TNT |
|---|---|---|---|---|---|---|---|---|---|---|
| Tris(methylnitramino-methyl)-amine | – | – | – | – | – | – | – | – | BMT | 106 |
| Tritolo (Ital) | See Trinitrotoluene | | | | | | | | | |
| Triton | See Trinitrotoluene | | | | | | | | | |
| Tritonal, 90/10 (TNT 90 & Al 10%) | – | – | – | ST | 111-14 | – | 6580 | 1.65 | BMT | 123 |
| Tritonal, 80/20 (TNT 80 & Al 20%) | – | – | – | ST<br>PDT<br>FET | 108-14<br>93-4<br>91 | –<br>1.72-1.75<br>1.72 | 6770 | 1.76 | TT<br>BMT | 153<br>124 |
| Tritonal/D2-95/5 | – | – | – | PDT | 85 | 1.67 | 6560 | 1.68 | BMT | 123 |
| Trojan Explosive (Nitrostarch 40, Na nitrate 37.7, Ba nitrate 20.0, oil 0.8 & DPhA or $CaCO_3$ 1.5%) | – | – | – | ST | 88 | – | 6100 | 1.6 | TT<br>BMT | 96<br>96 |
| | (Compare with Nitrostarch Demolition Explosive) | | | | | | | | | |
| Trotyl | See Trinitrotoluene | | | | | | | | | |
| Type 98 Expl, 60/40 (Japan) (TNAns 60 & HNDPhA 40%) | – | – | – | ST | 98 | – | 7000 | 1.5 | TT<br>BMT | 108<br>109 |
| | *Note*: There was also 70/30 Type 98 Explosive) | | | | | | | | | |
| Underwater Explosive (UWE) | Brit for Tritonal | | | | | | | | | |
| Urea Nitrate | – | – | – | – | – | – | – | – | TT<br>BMT | 91<br>92 |
| UWE | Abbr for Underwater Explosive | | | | | | | | | |
| Veltex | See Ref 30a, p 470 (Conf) | | | | | | | | | |
| Xylan Dinitrate | – | – | – | – | – | – | – | – | BMT | 107 |
| Xylitol Tetranitrate | – | – | – | – | – | – | – | – | BMT | 149 |

The above table was compiled in collaboration with Mr. Wm.H.Rinkenbach, Allentown, Pennsylvania (1961)

See page **B 266** for the meaning of Abbreviations

*Refs*: 1)H.Kast, SS **8**, 65-8 & 88-9 (1913) (Calcn of brisance by Kast's formula and brisance values for some expls detd by Cu Cylinder Compression Test) 1a)C.Herlin, SS **8**, 448-52 (1913) (Kast's formula for calcn of brisance is criticized and its modification is proposed. Herlin's formula is more complicated than Kast's) 1b)H.Kast, SS **9**, 33-4 (1914) (Kast's reply to Herlin. He does not agree with Herlin's criticism) 2)Marshall **2** (1917), 476

-501 3)H.Kast,"Spreng- und Zündstoffe", Vieweg,Braunschweig(1920),70 4)H.Kast,SS **15**,171-3 & 181-4(1920)(Brisance values for several expls; table) 4a)W.C.Cope,IEC **12**, 870(1920)(Brisance and some other expl characteristics for various military expls) 5)H.Kast,ZAngewChem **36**,75(1923)(Brisance values for some expls; table) 5a)H.Kast & A.Haid,ZAngewChem **38**,50-2(1925)(Brisance values and other expl characteristics for initiating expls and some other expls) 6)Naoûm, NG(1928),156,170,190,201,204-6,224-7,235-9, 241,247,249-50,277-9,319,322-3 & 349 6a)Sukharevskii & Pershakov(1932),102,120 & 150 7)Vennin,Burlot & Lécorché(1932),189-93 8)Marshall **3**(1932),155-7 9)W.Friederich & W.Brün,SS **27**,158(1932)(Brisance by Kast's formula) 10)Stettbacher(1933),48-52,62-4,95, 363 & 368 10a)W.Friederich,SS **28**,82-3(1933) (Calcn of "specific brisance") 11)L.Wöhler & F.J.Roth,SS **29**,9-11,46-8 & 74-7(1934)(Brisance of initiating expls by Lead Plate Punching Test) 11a)L.Wöhler & J.F.Roth,SS **29**,289 -92,331-4 & 365-8(1935) and Ibid **30**,11-14 & 39-42(1935)(Discussion on methods of calcg and detg brisance) 12)T.Urbański,SS**30**,68 -71(1935)(Comparison of calcg brisance by Kast's and Herlin's formulas; detn of brisance by Cu Cylinder Compression Test) 12a)J. Hackel & T.Urbański,SS **30**,98(1935)(Brisance and other expl characteristics for various nitrostarches) 13)A.Majrich & F.Sorm,SS **30**,295-9 & 337-40(1935)(Calcn of brisance and detn by Lead Plate Test and by Fragmentation Test) 14)Pepin Lehalleur(1935),54 & 78 15)Beyling & Drekopf(1936),57-9 16)N.Sokolov, "Theory of Explosives",Gosizdat,Moscow(1937),314(in Rus) 16a)M.Tonegutti,SS **32**,93-7(1937)(Brisance & other expl characteristics for PETN, RDX & TNT) 17)R.R.Stadler,SS **33**,338(1938) (Brisance and other expl characteristics of Ag acetylide,MF,LA & LSt) 18)Davis(1943), 3 & 210 18a)Blatt,OSRD **2014**(1944)(Expl characteristics for nearly all expls known before WWII) 19)Vivas,Feigenspan & Ladreda **4**(1944),58-62 & 118 20)Pérez Ara(1945),117 -18 21)G.M.Hopkins,PATR **1530**(1945)(Fragmentation efficiency values for some military expls) 22)D.R.MacDougall & E.H.Eyster, "Physical Testing of Explosives",NDRC Div 8,Interim Rept **PT-34**(1945),22(Plate Denting Values for 24 expls) 23)E.H.Eyster & D.P. MacDougall,"Evaluation of Fivonite as a High Explosive",OSRD **5627**(1945),11(Plate denting test values for Fivonite in comparison with some other expls) 24)All&EnExpls(1946), 17-18 & table betwn pp 57 & 58 24a)D. P. MacDougall et al, OSRD **5746**(1946) (Expl characteristics of many expls) 24b)Anon, "Summary Report of Division 8,NDRC",Vol 1, Washington,DC(1946) 25)S.Fleischnick,PATR **1595**(1946)(Fragmentation efficiency values for some expls) 25a)Muraour(1947),77-9 26)Stettbacher(1948),102-4,114 & 149 26a)W.C.Lothrop & C.R.Handrick,ChemRevs **44**,419-45(1949) (Relationship between performance and constitution of pure organic compds) 26b)A.D.Little, Inc,"Report on the Study of Pure Organic Compounds",Part 2(1949),Section 8(Relationship between heat of explosion and power & brisance values)(Conf)(not used as a source of info) 27)Belgrano(1952),5 & 39-41 27a)Stettbacher(1952), 131-3,144,152-3 & 189 28)Anon, "Military Explosives",TM **9-1910**(1955),60-4,97, 106,109,113,123,126,133,139,153,158,163,167, 172,176,181-3,185,188-9,191,193,195,197,201, 203,206 & 324(Brisance values and other expl characteristics for many military expls) 28a)W. E.Gordon et al,IEC **47**,1799(1955)(Trauzl Test values for HMX,MeDINA,RDX,tetryl & TNT) 29)Cook(1958),17 & 34 30)PATR **1740**,Revision 1(1958)(Expl characteristics fo US military expls) 30a)PATR **1740**,Supplement No 1 (1958)(Conf)(Not used as a source of info) 31)D.Price,ChemRevs **59**,801-25(1959)(Damage tests are a measure of expl performance and expl characteristics of Octol 70/25 and of some other HE's) 32)H.A.Whetmore,"Octol(HMX/ TNT): A Literature Survey",Literature Search No **10**,Tech Info Sectn,FREL,PicArsn,Dover, NJ(1960)(Conf)(Not used as a source of info) 33)W.H.Rinkenbach,Allentown,Pa; private communication(1961)

*Additional References on Brisance:*

A)L.H.Eriksen,"Study of Fundamental Properties of High Explosives",PATR **1192**(1942)[Tests were made to det if the claim is valid that the loading of different expls in layers results in the chge having a brisance value greater than the sum of the normal brisance values for the expls. From results of these tests, it was concluded that: a)While the max brisance for a compound-detonator can be obtained when it is loaded so as to have each succeeding layer or layers initiated by an expl having a higher deton velocity, no evidence was obtained that a compound-detonator consisting of separate

layers of different expls had a higher brisance value than the sum of the max values for the individual expls b)In the detonation of small charges, as used in the Sand Test, the brisance of TNT, tetryl and PETN is dependent upon the detonation velocity or brisance of the initiating chge. Thus, TNT when initiated by tetryl or PETN, gives brisance values higher than that obtained with MF as the initiator of detonation] B)H.Muraour & A.Demay,CR **223**,278-80(1946) & BrA **1947**,BI,148; Ibid,Chim&Ind(Paris) **56**, 463 -7(1946) & BrA **1947**,BI,291 [The brisance of MF and LSt(measured by the size of perforation produced in a lead plate) increased with compression up to 8000 kg/cm$^2$ when the expls were detonated with LA. The brisance of mixts of some primary expls was also increased on supercompression] C)H.Muraour,Chim&Ind (Paris) **66**,2803(1952) & BrA **1952**,BII,439. The views expressed by J. and J.Basset,CR **231**, 1440(1950) that the reduction in penetrating power of a shaped charge projectile when rotating, is due to compression of the explosive by centrifugal action and hence results in a decrease in brisance, are controverted. Compression of a secondary expl, such as TNT, does not reduce but increases the velocity of detonation and therefore the brisance. With primary expls, such as MF, the problem is more complex. Reduction in penetration of rotating shaped charges is usually ascribed to displacement of the nose by centrifugal action]

(*Note*: It has been proven that reduction in penetration of rotated shaped-charges is due to centrifugal action upon the jet itself. See numerous APG and CIT reports) D)T.Sakurai, JIndExplosivesSocJapan **13**,138-42(1952); **14**, 212-25(1953) and **16**,90-4(1955); CA **49**,5841 (1955); **49**,11283-4(1956) and **50**,17452(1956) (Discussion of various methods for measuring brisance) E)T.Sakurai,Kôgyô Kayaku Kyôkai Shi **18**,41-9(1957); **18**,225-36(1957); **18**,308-15 & 369-73(1957) and **19**,95-102, 181-92 & 236-40 (1958); CA **51**,9159 & 17167(1957); **52**,4987 (1958) and **53**,9671(1959) (Discussion of various methods for measuring brisance)

**Brisance-Detonation Velocity Relationship.** It has long been recognized that brisance is related to detonation velocity and efforts have been made to determine and express relationship betn these two characteristics of an expl [Refs 1 & 2

According to Rinkenbach(Ref 3), there was developed at PicArsn the following approx empirical relationship between brisance(B) in grams of sand crushed by 0.4-g sample when detonated in a 200-g bomb, and detonation velocity(D) in m/sec: $\log B = 3.45 \log(D/2450)$. A similar equation was later reported in a manual compiled at Aberdeen PG(Ref 4)

From sand test values (B) detd at PicArsn for ca 20 expls(using 0.4-g samples in both 200-g and 1700-g bombs) and from data available in the literature for their deton velocities (D) at approx their max densities, Rinkenbach obtained a nearly linear relationship on plotting B vs D. This permitted the following equations to be derived:

$D = 63.99B + 4234$ m/sec- for 200-g bomb

$D = 76.76B + 3965$ m/sec- for 1700-g bomb

By means of these equations the deton vel of an expl can be calcd with a mean accuracy of ca ±45 m/sec

*Note*: The above equations are not identical because the values for B obtained in the 1700-g bomb were somewhat lower than those obtained for the same expls in the 200-g bomb; but the relative orders of the expls with respect to B were the same in both bombs. The difference betw the B values for each expl in the two bombs is attributed to the different thicknesses of the layers of sand betw the cap(contg the chge) and the walls of the two bombs

Table II gives a comparison between D calcd by Rinkenbach and D obtained by averaging the various values in the literature

SEE TABLE II ON NEXT PAGE

Jones & Sheffield(Ref 5) also discussed the relationship between brisance(as detd by the Sand Test) and deton velocity but their data cannot be included here because it is classified

*Refs*: 1)H.Kast & A.Haid,ZAngewChem **38**,50-2 (1925) (Brief discussion on relationship betw brisance and detonation velocity for initiating expls: cyanuric triazide, LA, LSt, MF and 90/10-MF/$KClO_3$) 2)T.Urbański,SS **30**,68-71(1935) & CA **29**,4941(1935) [For expls such as TNT or AN expls, detonation velocity may be calcd from the equation $D = (24.9S_p)^2$, where D is detonation velocity, $S_p$ is compression of Cu cylinder in mm minus correction 0.16mm (Compression produced by a No 8 cap). This relationship does not hold for some chlorate expls] 3)W.H. Rinkenbach, "Study Fundamental Properties of High Explosives",PATR **1352**(1943) [Relationship betw brisance(detd by sand tests in 200-g and 1700-g

## Table II

Comparison of Detonation Velocities Calculated(from Sand Test Data) with those Published in the Literature

| Explosive | Brisance,B, grams Sand Crushed in 1700-g Bomb | Detonation Velocity,D,m/sec Calcd by Rinkenbach | Detonation Velocity,D,m/sec Taken from the Literature | Density,d, g/cc |
|---|---|---|---|---|
| Pentaerythritol tetranitrate (PETN) | 57.9 | 8409 | 8350 | 1.67-1.70 |
| Mannitol Hexanitrate | 56.4 | 8294 | 8260 | 1.73 |
| Cyclonite (RDX) | 53.2 | 8049 | 8180 | 1.65 |
| Ethylenedinitramine(EDNA) | 48.4 | 7680 | 7620 | 1.5 |
| Tetryl | 47.7 | 7626 | 7680 | 1.60-1.71 |
| Dinitroethyleneurea | 45.0 | 7419 | 7660 | 1.6 |
| Trinitrobenzene (TNB) | 43.2 | 7282 | 7400 | 1.65 |
| Picric Acid | 41.8 | 7174 | 7300 | 1.63-1.71 |
| Trinitroanisole(TNAns) | 41.7 | 7166 | 7150 | 1.59-1.7 |
| Trinitrotoluene (TNT) | 41.2 | 7128 | 6970 | 1.60 |
| Trimonite | 39.9 | 7028 | 7020 | 1.60 |
| Diazodinitrophenol(DADNPh) | 39.7 | 7012 | 6900 | 1.58 |
| Trinitroethylbenzene(TNEB) | 36.3 | 6751 | – | – |
| Trinitroxylene (TNX) | 34.5 | 6613 | 6600 | 1.51 |
| Ammonium Picrate (AP) | 33.7 | 6552 | 6775 | 1.55 |
| Amatol,40/60 | 33.4 | 6529 | 6470 | 1.54 |
| Amatol,50/50 | 34.0 | 6575 | 6430 | 1.55 |
| Dinitrobenzene (DNB) | 23.6 | 5777 | 6100 | 1.56 |
| Mercuric Fulminate (MF) | 22.5 | 5669 | 5400 | 4.2 |
| Lead Azide (LA) | 18.6 | 5393 | 5300 | 4.6 |
| Lead Styphnate (LSt) | 10.9 | 4802 | 5200 | 2.9 |

bombs) and detonation velocities] 4)All&EnExpls (1946),18[Brisance can be calcd with a small margin of error by using the equation:LogB= 3.53log(D/2500), where B = grams of sand crushed by 0.4-g sample and D = deton velocity in m/sec] 5)M.M.Jones & O.E.Sheffield,"The Sand Bomb Test Considered as a Fragmentation Problem",PATR **2424**(1957)(Conf) (Not used as a source of info)

**Brisance Test Methods.** Early test methods(beginning in this century) for detg brisance included *Lead Block Compression Test*(LBCT) (Hess' method, also known as Austrian Method) and *Copper Cylinder Compression Test(CCCT)* (Kast's Method, also known as German Method). In the LBCT, a chge of expl(50 or 100g) is detonated on a steel plate covering a lead cylindrical block 40-mm diam and 30-mm high. The resulting compression of the block is measured and compared with the compression produced on detonation of a standard expl, such as TNT or PA. In the CCCT the compression of a copper cylinder(crusher) 7-mm diam and 10-mm high serves as a measure of brisance(Refs 1,1a,3,3a,4,5,8,9,10,10a,11,14,15 & 16) (See also under Compression Tests)

A modification of these tests, known as the *Quinan Test*, is described in Vol 1,p XXI of this Encyclopedia and in Refs 6,9 & 13a

The *Hopkinson Pressure Bar Method* is briefly described in Ref 7, Addnl Ref a and in Vol 1,p XVI

The methods currently used in the US include: a)Sand Test(ST). It is described in Vol 1,p XXI XXII and in Refs 4,17,18 & 19. According to some investigators this test measures the "energy of explosion" rather than brisance b)*Plate Denting Test*(PDT) and *Plate Cutting Test*(PCT). These tests are briefly described under Plate Tests in Vol 1,p XX(See also Refs 12,13,14,17 & 18) c)*Fragmentation Efficiency Test*(FET) is briefly discussed as Fragmentation Test in Vol 1,p XII (See also Refs 8,14,16,17 & 18) d)*Fragment Velocity Test*(FVT) is briefly described in Vol 1,p XIII(See also Ref 18)

Stettbacher(Ref 2 & Ref 8,p 361) proposed a test which was claimed to det simultaneously brisance and energy. In this method, known as *Strahlungsprobe*(Radiation Test), a finely powdered expl (ca 50g), packed lightly in a thick Fe or Ni crucible, was placed in the center of a square plate of soft Fe, 6.8mm thick, supported on the top of a hollow cylinder. After initiating the expl by means of 1-2g MF-LA mixt, the detonating effect was measured by the depth of impression (dent) made in the Fe plate by the crucible, by the amt of radial and concentric stratiation around the dent and the amt of scaling. Sometimes the plate around the dent was colored blue. Stettbacher claimed that the deeper the dent the more powerful was the expl and that the brisance and detonation velocity may be approx estimated by the appearance of the surface of the plate. The deeper the blue color and the coarser, more numerous and deeper stratiations, the greater was the brisance and the higher was the deton velocity. The total energy was expressed in mm of depth of the dent

Another method for measuring the brisance, the so-called *Stanzprobe* (Punch Test), was developed in Germany and is described in Addnl Ref F. In this method the explosive was cast or pressed into a seamless steel tube which was centered vertically on a lead plate placed over a pit or "shot hole".The expl chge, when initiated by a No 8 blasting cap and a booster chge of pressed PA, detonated and punched a hole through the lead plate. The diam of the hole was a measure of brisance. According to to Dr Hans Walter, now at Picatinny Arsenal but formerly with the German Wehrmacht during WWII, when a highly brisant expl was tested it was sometimes the practice to force part of the chge beyond the end of the tube. This variation of the test was used to measure the self-sustaining detonation props of the expl when unconfined

The French methods for detg brisance:"Epreuve des petits plombs" and "Epreuve de Chalon" will be described under Compression Tests

*Refs on Brisance Test Methods:* 1)N.W.Berger,SS **1**,150-2 & 169-72(1906)(Detn of brisance in Norway by Lead Block Compression Test and by Fragmentation Test) 1a)H.Kast,SS **8**,88-9(1913) (Detn of brisance by Brisance Meter, which is also called Copper Cylinder Compression Test) 2)A. Stettbacher,SS **11**,249-50(1916); JSCI **36**,101(1917) & CA **11**,2733(1917)(Detn of brisance and energy by Iron Plate Denting Test) 3)Marshall **2**(1917) (Detn of brisance by Brisance Meter) 4)C.E. Munroe & J.E.Tiffany,"Physical Testing of Explosives",USBurMines,Bull **346**(1931),106-15 (Detn of brisance by Small Lead Blocks Test, by Sand Test and by Nail Test) 5)Sukharevsky & Pershakov(1932),120-1 & 126(Detn of brisance by Sand Test and by Cu & Pb Compression Tests) 6)Vennin,Burlot & Lécorché (1932),192-3(Detn of brisance by Quinan apparatus) 7)Marshall **3** (1932) (Detn of brisance by Hopkinson's Pressure Bar Method) 8)Stettbacher(1933),50-1,361 & 365-7 (Detn of brisance by Fragmentation Test, Lead

Block Compression Test and Copper Cylinder Compression Test) 9)Pepin Lehalleur(1935),63-4 & 78(Detn of brisance by various methods) 9a)A. Majrich & F.Sorm,SS **30**,295-9 & 337-40(1935) (Detn of brisance by Fragmentation Test and by other methods) 10)Beyling & Drekopf(1936),64-5 (1936) (Detn of brisance by Cu Cylinder Compression Test) 10a)Reilly(1938),68(Brief description of Kast's Brisance Meter) 11)Meyer(1943),375(Detn of brisance by Lead Block Compression Test) 12)Vivas,Feigenspan & Ladreda **4**(1944),118-20 (Detn of brisance by Plate Cutting Test) 13)L.C. Smith et al,OSRD **5746**(1945),20-2(Detn of brisance by Plate Denting Test) 13a)Pérez Ara(1945),118 (Quinan Test) 14)Stettbacher(1948),89-90,99,110 & 114-17 (Detn of brisance by Plate Denting Test, Copper Cylinder Compression Test and by Fragmentation Test) 15)Belgrano(1952),39-41(Detn of brisance by Lead Block Compression Test) 16)Stettbacher(1952),113-19,141-2 & 146-9(Various tests for detg brisance) 17)Anon,"Military Explosives",TM **9-1910**(1955),60-5(Detn of brisance by Sand Test, Plate Denting Test and Fragmentation Test) 18)PATR **1740**,Revision 1(1958) (Brief description of Sand Test, Plate Denting Test, Fragmentation Test and Fragment Velocity Test) 18a)T.Sakurai,JIndExplsSoc(Japan) **19**, 181-92 & 236-40(1958); **20**,57-65(1951) (Brisance tests) 19)A.J.Clear,"Standard Laboratory Procedures for Sensitivity, Brisance and Stability of Explosives", PATR **FRL-TR-25**(1961),24(Detn of brisance by Sand Test) [This report is a revision of PATR **1401**(1944), compiled by W.H.Rinkenbach, and of **1401**, Revision 1(1950]

*Additional Refs on Brisance Test Methods*: A)R.Robertson,JCS **119**, 19-24(1921)[The usual methods for measuring brisance(such as listed above) are considered inadequate and the method known as Hopkinson's Pressure Bar is proposed. In this method it is possible to det the blow or pressure developed by an expl over a small measurable interval of time and this is a measure of the violence(brisance) it exhibits. The principle on which the determination of the pressure is based depends on the fact that when a chge is fired against the end of a cylindrical steel bar, ballistically suspended, a wave of compression travels along the bar and is reflected at the far end as a wave of tension. For details of measuring pressure by this method see B.Hopkinson,PhilTrans **213A**,437(1914) and Vol 1 of this Encyclopedia, p XVI. Following are results of tests by this method expressed as pressure in tons per $in^2$ in $0.5 \times 10^{-5}$ sec(with constant pellet interposed): TNT 55.0(d 1.55,cast), PA 54.0(1.6,cast, tetryl 57.8(1.55,pressed), m-TNX 43.7(1.45), m-DNB 32.9 (1.2), 2,4-DNT 31.1(1.2), DNN(crude) 14.1(1.2) & MNB 4.0(1.18, liq)] B)L.Wöhler & F.J.Roth,SS **29**,9-11, 46-8 & 74-7(1934); CA **28**,3901-2(1934) (Objections to existing methods of calcg brisance and to detg it by compression of Cu or Pb cylinders are cited. A new method for detg brisance is described in which 0.6g of a mixt of NaCl with an insensitive expl such as TNX is interposed betw the chge of expl to be tested and a 4-mm Pb plate. The chge is pressed into a piece of Cu tubing(35 or 50mm long & 7mm ID, with 1mm wall) and detonated by a suitable initiator. The effect on the Pb plate is dampened by the intervening layer of NaCl/TNX mixt to an extent depending on its percentage content of NaCl which is varied until the effect just produces a clean cylindrical perforation in the plate. The results of testing 24 expls are tabulated) C)L.Wöhler & J.F.Roth,SS **30**,12-13(1935) (Method for detg the brisance of liquid and plastic expls, using the lead plate) D)T.Urbański,SS **30**,68-71(1935) & CA **29**,4941(1935) (1935)(Detn of brisance by a modified Kast Copper Cylinder Compression Test method using 7× 10-mm Cu cylinders and omitting lead plates) E)E.Calvet,AnnFaculté SciMarseille **16**,3-13(1942) & CA **41**,2575-7(1947)(Determination of brisance by means of a special apparatus. The values,B, detd by this method were TNT 44, PA 47, tetryl 61 & RDX 77) F)P.Naoúm & A.Berthmann, "Explosivstoffe",p 373 in Vol II of Chemische Technologie"(Organische Technologie II) by K.Winnaker & E.Weingaertner,Carl Hanser Verlag,München (1954) [Detn of brisance by Stanzprobe(Punch Test) der Chemisch-Technischen Reichsanstalt (Berlin)]

**Briska Detonator**(Briska Kapsel in Ger). A brief description is given in PATR **2510**(PB Rpt 161270 (1958), p Ger 23. Briska caps No 6 & No 8 have been used by the British[See also Taylor(1952), 11]

**Britainite.** An expl invented by Von Dahmen consisted of AN 70.8, $KNO_3$ & $KClO_3$ 20.4, naphthalene 7.1 & moisture 1.7%

*Ref*: Daniel(1902),83

**British Ammonals.** See under British Military Explosives and under Ammonals, Vol 1,pp A289, A290 & A291-R

**British Ammonium Nitrate Dynamites.** See Vol 1,p A368(table)

**British Commercial Explosives.** Advances in British coml HE's is discussed in detail by Taylor (Ref 1). See also Ref 2, British Ammonals in Vol 1,pp A289, A290 & A291-R and British Ammonium Nitrate Gelatin Dynamites in Vol 1,p A368(table)
*Ref:* 1)J.Taylor,Research(London) **1947**,67-76(a review with 59 refs) & CA **42**,2105(1948) 2)Taylor & Gay(1958),1-50 & 86-106

**BRITISH MILITARY EXPLOSIVES AND PROPELLANTS.** Following list includes Brit expls and proplnts, some of them obsolete:
*Abel's Explosive.* See Abel Powder or Picric Powder in Vol 1,p A1-R
*Alumatol.* See Vol 1,p A141-R
*Amatex 9.* See Vol 1,p A157-R
*Amatols.* See Vol 1,p I62-R
*Ammonals.* Used in demolition and cratering charges. Their compns included: a)AN 65, TNT 15, Al 17 & charcoal 3% b)AN 65, TNT 15, Al 10 & charcoal 10% (Ref 1,p 84)(See also Vol 1,p A261-R & Ref 2,p 26)
*Note:* Brit expls Alumatol, Burrowite, Minols and Nobel's 704 also belong to the class of expls known as Ammonals
*Baratol:* The compn contg TNT 90 & Ba nitrate 10% was used in A/T mines, grenades & A/S bombs(Ref 1,p 89)(See also Baratol in this vol)
*Black Powder.* See this volume
*Burrowite.* One of the Brit Ammonals(See also Burrowite in this vol)
*CE*(Composition Exploding)(Tetryl). Used in standard boosters and as bursting chge in chem ammo(Ref 1,pp 91 & 93)
*Composition A*(RDX/Beeswax-91/9). Used as filler for some shells & grenades(Ref 1,pp 121-2)
*Composition B.* See under Cyclotol
*Cordite.* Brit standard propellant(see Cordite)
*Cyclonite.* See RDX
*Cyclotol.* Mixts of RDX 50 or 60 & TNT 50 or 40%. The mixt RDX/TNT/Wax-59/40/1 is called Composition B in the US and RDX/TNT-60/40, Composition B2. Cyclotols were used by the Brit as bursting chges in GP, MC, HC, A/S, Fragn & Parachute bombs and in some shells(Ref 1,pp 123-4)
*DNB/RDX Mixture.* See RDX/DNB-60/40 Mixture
*DBX* (Depth Bomb Explosive)(RDX/AN/TNT/Al--21/21/40/18). Used as a bursting chge in depth bombs(Ref 1,p 130)
*Guncotton Explosive.NC*(ca 13%N), contg ca 13% $H_2O$. Used in 1-lb demolition blocks(Ref 1,p 149)
*HMX* (His Majesty's Explosive or High Melting Explosive). See Cyclotetramethylenetetranitramine
*Lead Azide*(LA). Used in friction primers(mixts of LA/$Sb_2S_3$/$KClO_3$/Abrasive) and in detonators (in conjunction with LSt) (Ref 1,p 68)
*Lead Styphnate*(LSt). Used in conjunction with LA in detonators(Ref 1,p 70)
*Lyddite.* Brit designation for cast Picric Acid
*Mercuric Fulminate*(MF). Used in the following primer mixts: a)"A" mixture MF 25, $KClO_3$ 58.3 & $Sb_2S_3$ 16.7% b)"B" mixture MF 11, $KClO_3$ 52.5 & $Sb_2S_3$ 36.5% c)"C" mixture MF 32, $KClO_3$ 45 & $Sb_2S_3$ 23% d)"D" mixture MF 60 & $KClO_3$ 40%(Ref 1,p 64)
*Minol II*(TNT/AN/Al-40/40/20). Used in sea mines, depth charges and A/S & HC bombs(Ref 1,pp 85-6)
*Nobel's 704*(AN/TNT/Al-69/15/16. Used in granades(Ref 1,pp 84 & 86)
*Nobel's 808.* No info on its compn at our disposal. Used in some bombs
*PE-2* (Plastic Explosive-2). Same as Amer Composition C
*Penthrite*(PETN). Used as the core in Cordtex Detonating Fuse(Ref 1,pp 135-6)
*Pentolite* (PETN 50 & TNT 50%). Used as bursting chge in MC & Fragn bombs, A/P mines and 40-mm shells(Ref 1,pp 138-9)
*Picric Acid*(PA). Used in boosters(pressed) and in grenades & some shells(cast, under the name Lyddite)
*Picric Powder.* Same as Abel's Explosive
*RDX* (Research Department Explosive)(Cyclonite). Used in Composition A, Composition B, DBX, PE-2, RDX/DNB mixture & Torpex(See also Cyclotrimethylenetrinitramine)
*RDX/DNB-60/40 Mixture.* Lt yel cast expl with characteristics intermediate betw TNT & Comp B and about as sens as PA. Its specific use was not stated but it could have been used as a bursting chge(Ref 1,p 135)
*Shellite*[called in the US 70/30 Tridite(PA/DNPh -70/30)]. Used as the bursting chge in AP bombs and shells(Ref 1,pp 99-100)
*Tetryl* (US). See CE(Composition Exploding)
*Tetrytol* (Tetryl/TNT-75/25). Used as bursting chge in some bombs and as a booster chge(with the addn of wood meal to decrease the density and thereby increase the sensitivity)(Ref 1,p 94)
*TNT.* See Trotyl
*Torpex I* (RDX/TNT/Al-45/37/18 or RDX/TNT/Al/Beeswax-44/37/18/1) and Torpex II (RDX/TNT/Al-42/40/18). Used in MC & A/S bombs, aerial & submarine torpedoes and in rockets(Ref 1,pp 128-9)
*Tridite.* See Shellite

*Trinitrotoluene*. See Trotyl
*Tritonal* (US). See UWE
*Trotyl* (TNT). Used as bursting chge in GP, MC, SAP, A/S & Fgran bombs; in land mines, rockets, aerial torpedoes and shells of all types (Ref 1, p 75)
*UWE* (Underwater Explosive) (TNT/Al-80/20). Used in lieu of Minol II as bursting chge for 4000-lb HC bombs (Ref 1, p 88) and considered for use as an underwater explosive
*Abbreviations*: **A/P** antipersonnel, **AP** armor-piercing, **A/S** antisubmarine, **A/T** antitank, **Fragn** fragmentation, **GP** general purpose, **HC** high capacity, **MC** medium capacity and **SAP** semi-armor-piercing
*Refs*: 1) All&EnExpls (1946) 2) Taylor & Gay (1958), 26

**British Propellants.** See Cordites

**British Tests.** See Physical Tests for Determining Explosive and Other Properties Vol 1 and specifically the following British tests: a) *Ballistic Pendulum Test*, p VII; b) *Exudation* (or sweating) Tests, p XI; c) *Fl Test* (Figure of Insensitiveness Test); p XII *Fragment Gun*, p XII; d) *Friction Sensitivity Tests*, p XIII; e) *Hopkinson's Pressure Bar Test*, p XVI; and f) *Silvered Vessel Test or Waltham Abbey Silver Vessel Test*, p XXIV

**British Weapons.** No information at our disposal

**Britonites.** Brit coal-mine expls manufd after WWI by the British Explosives Syndicate, Ltd, Pitsea. They used to be on Permitted List, but have now been repealed. The original compn contained NG 26, K nitrate 32.7, woodmeal 41 & Na carbonate 0.3%. Later compns were: **No2**, which contained NG 24, K nitrate 30, woodmeal 38 & Amm oxalate (cooling agent) 8% and **No3**, which contained NG 24.5, Na Nitrate 28, woodmeal 35.5 & NaCl 12%. Power (swing of ballistic pendulum) was 2.26" for No 2 and 2.17" for No 3, vs 3.27" for std Gelignite. Limit charge for both No 2 & No 3 was 24oz
*Refs*: 1) Marshall **I** (1917), 376 2) A.Marshall, "Dictionary of Explosives", Churchill, London (1920), 15-16

**Britonite.** A mixt of K nitrates, Amm oxalate, NG & woodflour
*Ref*: Cond Chem Dict (1942), 288 (not found in later editions)

**Brittle Point or Brittleness Temperature.** The temp at which a compd or compn becomes too brittle to be used for specific purposes. This prop is of particular importance in instances where proplnts, plastic expls, rocket or JATO chges are intended for use or storage in colder climates such as Alaska, Northern Canada or Siberia

Many methods for testing the brittleness of materials such as plastics & rubbers were proposed, among them: a) Bent Loop Test (Ref 1) b) Bell Telephone Laboratory Test (Refs 2, 3 & 4) c) Swinging Pendulum Test (Refs 5 & 11) d) Du-Pont Co Test (Ref 6) e) Charpy Test and f) Izod Test (Ref 7). None of these methods seems to be very reliable except the method developed at the Bell Telephone Lab (Ref 4). It was tentatively adopted in 1943, by the ASTM as the D476-43T Test and later modified, to be known as D476-57T (Ref 12). This test was adopted by the US Govt for testing organic plastics and is incorporated in Federal Specification L-P-406b (Ref 13). In this procedure, a specimen (such as a strip of plastic, hard rubber, propellant, etc), 1" long, 0.25" wide and 0.075" thick, is placed in a low-temp bath where it is brought to the desired temp of testing. The sample is then clamped in a special apparatus and subjected to an impact of a striker, which can be either motor-driven or actuated by a solenoid. If the specimen breaks, the test is repeated at higher temps until no failures occur in 5 out of 10 tests. This method has been used for detg the brittle point of some propellants, such as Aerojet, Arcite 101, JPN, Thiocol, etc, but the results of these tests are classified

A different method was used at NOTS, China Lake, Calif (Ref 8) for testing double-base proplnts, but the results are also classified. The same may be said about testing the brittleness of ball powder at Frankford Arsenal, Phila (Ref 10). Brittleness of some proplnts was detd at PicArsn by the compression method (Ref 9) but these results are classified
*Refs*: 1) S.M.Martin, Jr, Rubber Age (NY) **52**, 227 (1942) (A bent-loop test, incorporated later by ASTM as D736-43T) 2) M.L.Selker et al, IEC **34**, 157-60 (1942) (A simple app in which a specimen, in the form of a strip attached to a movable shaft, sharply strikes a stationary steel arm) 3) A.R.Kemp et al, IEC **35**, 488 (1943) (Modification of the previous app by fitting it with an electric motor and a set of gears in an attempt to control the rate at which the sample strikes the arm) 4) R.E.Morris et al, IEC **35**,

864(1943)(Further modification of Selker and Kemp methods to give better control of temp and higher velocities at point of impact) 5)C.K. Chatten et al,Rubber Age(NY) **54**,429(1944)(A test device in which a swinging pendulum imparts a blow to the specimen) 6)H.G.Bimmerman & W.N.Keen, of the DuPont Co,IEC,AnalEd **16**, 588-90(1944)(An app using alternating current solenoid as a source of power permits control of the velocity of the device inducing the deformation) 7)G.S.Brady," Materials Handbook", McGraw-Hill,NY(1951),852-3(A brief description of the Charpy & Izod methods) 8)J.M.Nielsen & F.M.Ernsberger,"Some Factors Affecting Brittle Temperatures of Double-Base Propellants"; NAVORD Rept **2034**,NOTS **708**(1953)(Conf) 9)E.McAbee,"Applied Research on Rocket Propellants-Test Methods-Mechanical Properties", PicArsnTechRept No **1979**(1953)(Conf) 10)W.F. Ashly, " Brittle Fracture of Ball Propellant", Frankford Arsenal Rept No **R-1360**,Philadelphia, Pa(1956)(Conf) 11)J.P.Frankel,"Principles of the Properties of Materials",McGraw-Hill,NY (1957),184-5(A brief description of a Swinging Pendulum Method for testing brittleness) 12) 12)ASTM Standards,Part 9,Philadelphia,Pa(1958), pp 355-60 13)US Federal Specification L-P -406b),Method 2051

**BRL-1.** NC-polyester urethane, high performance solid proplnt system described by Davis & Lenk (Ref)
*Ref*: K.E.Davis & C.T.Lenk,Wyandotte Chem Corp Tech Note, Contract DA-20-018-ORD-13364, 1 Aug 1958 to 1 Aug 1959(Conf)

**Broberg and Wildrick** of Dover,NJ,USA, patented in 1895 expls contg $NaNO_3$ 40 to 80, nitronaphthalene 10 to 20, sulfur 5 to 12, $KClO_3$ 1 to 15% & nitrated resin (amt not specified)
*Ref*: Daniel(1902),84

**Brockite.** A mixt of Al & Ba chlorate
*Ref*: CondChemDict(1942),288(not found in later editions)

**Bromates.** The salts of bromic acid contg the monovalent radical $^-BrO_3$. These salts are generally considered to be more toxic than chlorates, causing central nervous system paralysis. They form metahemaglobin, but less actively than chlorates. Bromates in the form of gas, vapor or dust represent mod fire hazard. They are powerful oxidg agents and react with oxidizable(reducing) materials more or less violently, very often causi combustion (Ref 4). Props of the more impo. ant bromates are described by Mellor(Ref 3), Sax(Ref 4) and others:

*Aluminum Bromate*, $Al(BaO_3)_3 \cdot 9H_2O$, mw 572.9; crysts, mp 62.3°, bp dec(Ref 4,p 260)
*Ammonium Bromate*, $NH_4BrO_3$, mw 145.96; col crysts, mp expl(Ref 4,p 275)
*Barium Bromate*, $Ba(BrO_3)_2 \cdot H_2O$, mw 411.21; wh crysts, mp 260°(dec)(Refs 3a,p 649; 4,p 330 & 6,p 125)
*Cadmium Bromate*, $Cd(BrO_3)_2 \cdot H_2O$, mw 386.3; col rhmb crysts, mp dec;powerful oxidizer (Refs 4,p 418 & 6,193)
*Calcium Bromate*, $Ca(BrO_3)_2 \cdot H_2O$, mw 386.3; monocl crysts, mp 180° (loses w of crystn) (Ref 4,p 425)
*Cupric Bromate*, $Cu(BrO_3)_2 \cdot 6H_2O$, mw 427.5; bl-grn cubic crysts, mp dec 180° & 200° (loses w of crystn)(Ref 4,p 515)
*Lead Bromate*, $Pb(BrO_3)_2 \cdot H_2O$, mw 481.1; monocl crysts, mp dec 180°(Refs 4,p 816 & 6, p 657)
*Mercuric Bromate*, $Hg(BrO_3)_2 \cdot 2H_2O$, mw 492.3; crysts, mp dec 130-140°, highly toxic(Ref 4,p 856)
*Mercurous Bromate*, $Hg_2(BrO_3)_2$, mw 657.1; crysts, mp dec, highly toxic (Ref 4,p 865)
*Nickel Bromate*, $Ni(BrO_3)_2 \cdot 6H_2O$, mw 422.6; monocl crysts, mp dec(Ref 4,p 933)
*Potassium Bromate*, $KBrO_3$, mw 167.0; wh crysts, mp 434° dec at 370°(Refs 4,p 1037 & 6,p 926)

*Silver Bromate*, $AgBrO_3$, mw 235.8; wh powd. mp dec(Ref 4,p 1103 & 6,p 1022)
*Sodium Bromate*, $NaBrO_3$, mw 150.9; wh crysts, mp 381°(Refs 3a,p 649; 4,p 1113 & 6,p 1036) (See also Refs 4a & 5)
*Strontium Bromate*, $Sr(BrO_3)_2 \cdot H_2O$, mw 361.5; col-yel monocl hygr crysts, mp 120°(loses w of crystn), bp dec 240°(Refs 4,p 1138 & 6,p 1080)
*Zinc Bromate*, $Zn(BrO_3)_2 \cdot 6H_2O$, mw 429.3; wh delq powd, mp 100°, bp 200°(loses w of crystn) (Ref 4,p 1267)

Junk(Ref 1) found that *K bromate*, present as an impurity in $KClO_3$ prepd by the electrolytic method, may cause spontaneous ignition on contact with combustible materials. Small amts of $KBrO_3$, up to 0.15%, are permissible in $KClO_3$. Main(Ref 2) patented a detong compn composed of MF 70-95 & a bromate, such as $KBrO_3$, 5-70%; and claimed the bromate gave a higher detong force than a similar mixt contg chlorate. Marshall (Ref 2a) claimed that $KBrO_3$ has a harmful effect on the stability of expls
*Refs*: 1)A.Junk,SS **8**,412-4 & 430-2(1913) & CA **8**,421(1914) 2)W.L.Main,USP 1147958(1915) & CA **9**,2592(1915) 2a)Marshall **2**(1917),689 3)Mellor **2**(1922),338ff 3a)Kirk & Othmer **2** (1948),649 4)Sax(1957),381 4a)S.Kay,PATR **1947**(1957) (Purity detd by titration in non -aqueous medium) 5)USSpec MIL-S-11173 6)CondChemDict(1961),193,926 & 1036

**Bromazide.** See Bromine Azide, Vol 1,p A525-R

**Bromides.** Binary salts contg negative monovalent bromine. They are usually soluble in w. According to Sax(Ref 4), the most common inorg salts are *sodium, potassium, ammonium, calcium & magnesium* bromides. When ingested or inhaled the inorg bromides produce depression, emanciation and, in severe cases, psychosis and mental deterioration. Bromide rashes("bromoderma"), esp of the face and resembling acne and furunculosis, often occur when bromide inhalation or administration is prolonged. The most common org bromides, *methyl & ethyl* bromides, are vol liquids of rel high toxicity

According to Wachtel(Ref 1,p 185), the org arsine compounds will possibly belong among the most efficient war gases in future wars. If the place of O in compds of the type R-As=O is taken by halogens and other radicals, the resulting compds are extremely violent irritants and may also be highly toxic. The irritant effect is more vident if the halogen is substituted for O and directly bound with the As atom. Wachtel(Ref 1,p 191) lists as fatal the following bromides in concns over 3000 mg/m³: *dimethylarsinebromide*[$(CH_3)_2$=As-Br]; *diphenylarsinebromide*, [$(C_6H_5)_2$=As-Br];*o-chlorophenylphenylarsinebromide*, $C_6H_5$>As-Br; $Cl.C_6H_4$>
*methylarsinedibromide*, $CH_3$-As=$Br_2$; *ethylarsinedibromide*, $C_2H_5$-As$Br_2$; *phenylarsinedibromide*, $C_6H_5$-As=$Br_2$ & *arsenic tribromide*, As=$Br_3$(Ref 4)
*Nitrosyl bromide*, NOBr, mw 109.92; brn gas or dk-brn liq, fr p -55.5°, bp -2°C; formed by passing NO into bromine at -15°(at RT $NOBr_3$ is formed)(Ref 1). According to Sax(Ref 4), this compd is severely toxic since single exposure can cause injury or mucous membrane sufficiently serious to threaten life or cause physical impairment

Seel et al(Ref 3) have studied the reaction of NOBr with iodides & with azides. The reaction with iodies in $SO_2$: $2NOBr + 2I^- \rightarrow 2NO + I_2 + 2Br^-$, provides a basis for detecting & detg the amt of nitrosyl halide
*Refs:* 1)C.Wachtel, "Chemical Warfare", ChemPublgCo, Brooklyn, NY(1941), 185 & 191 1a)Kirk & Othmer **2**(1948), 646-7 2)Partington (1950), 322 & 558 3)F.Seel et al, ZAnorgChem **264**, 298 & 311(1951) & CA **46**, 6984(1952) 3)Sax(1957), 316(for $AsBr_3$), 330(for $BaBr_2$), 382(for bromides) & 959(for NOBr)

**Brominated Nitroparaffins.** Some of these compds, contg both Br and $NO_2$ groups, are expl. The following are typical examples:
*Potassium Bromodinitromethane*, $KCBr(NO_2)_2$, yel, triclinic crysts, d 1.25 at 20°, easily sol in hot w, diffc sol in cold w; insol in alc & eth; expl at 145-164°(Ref 1). The existance of the monohydrate, $KCBr(NO_2)_2 \cdot H_2O$, was reported but not confirmed
*Silver Bromodinitromethane*, $AgCBr(NO_2)_2$, golden yel, shiny crysts, prepd by the action of $AgNO_3$ on potassium bromodinitromethane; expl on heating(Ref 1)
*Dibromodinitromethane*, $Br_2C(NO_2)_2$, heavy yel oil, mp 7.4°, bp 78-80° at 19mm, 86° at 23mm, d 2.395 25°/4°, $n_D$ 1.522 at 20°; may be prepd by methods given in Ref 2; expl at 158°
*Bromotrinitromethane*, $BrC(NO_2)_3$, fr p 17-18°, bp 56° at 10mm, d 2.044 at 15/4° sl sol in w; may be prepd by methods given in Ref 3; expl on

heating
*Refs:* 1)Beil **1**, 78 & [44] 2)Beil **1**, 79, (21) & [44] 3)Beil **1**, 79, (21) & [46]

**Brominating Agents; Danger of Explosion.** Solid brominating agents should be investigated, with regard to their expl hazard, on a small scale, before they are recommended for industrial use on a larger scale. For example, when *tri-N -bromomelamine* was added to allyl alc, the mixt exploded after 15min at RT
*Ref:* J.A.Vona & P.C.Merker, C & EN **30**, 1916(1952) & CA **46**, 7329(1952)

**Bromination of Phenols** was studied by G.Heller et al. Some of the products obtained during these investigations were expl
[See also 3,5,6-Trinitro-2-aminophenol and its brominated product(Vol 1,p A244-L under Aminophenols)]
*Ref:* G.Heller et al, JPraktChem **129**, 211-56 (1931) & CA **25**, 2128-9(1931)

**Bromine**(Brom in Ger & Rus, Brome in Fr, Bromo in Ital & Span), Br, at wt 79.92; dk-red fuming liq or rhomb crysts, fr p -7.3°, bp 58.7°, d 2.93 at 59° & 3.12 at 20°; vap press 175mm at 21° & 1atm at 58.2°, vap d 5.5; sol in alc, chlf, eth & w. Elementary bromine never occurs in nature but is found mainly as bromides of alk metals, in natural waters, brines & sea water. Bromine was discovered in 1826 by A.J.Balard in the mother liquors of sea water, and named from the Greek "Bromos", meaning stench(Refs 1,2,3,5, & 6). It can be prepd in the lab by heating K bromide with dil $H_2SO_4$ & $MnO_2$ in a retort; prepd technically from Stassfurt or other bromides by passing chlorine & steam into the soln in a tower packed with porcelain(Ref 7). Bromine is a very powerful oxidg agent

The toxicological action of Br is essentially the same as that of Cl, being an irritant to the mucous membranes of the eyes and the upper respiratory tract. Severe exposure may result in pulmonary endema. Chronic exposure is similar to the therapeutic ingestion of excessive bromides (qv). The MAC(max allowable concn) is 6.5mg/m$^3$ of air or 1ppm in air(Ref 9)

It is used for the separation of minerals (for example, gold extraction), in making dyes, and as a local anesthetic, antispasmodic & sedative medicine. It is also used to some extent as a disinfectant, absorbed in sticks of diatomite brick(Refs 7 & 9). Bromine was used during WWI, to a very limited extent, in France("Sulvanite") & in Germany("Brom") as a CWA(Ref 4)
*Refs:* 1)Mellor **2**(1922), 90, 101 & 105; Suppl **2**, Pt 1(1956), 689-723 2)Gmelin, Syst Nr **7**(1931), 34-166 3)Thorpe **2**(1938), 106-16 4)Wachtel (1941), 142 & 154 5)Hackh's(1944), 144 6)Kirk & Othmer **2**(1948), 629-45 7)Partington(1950), 317-19 8)Faith, Keyes & Clark(1950), 143-8 & 2nd ed(1957), 165-70 9)Sax(1957), 382

**Bromine Azide.** See Vol 1,p A525-R

**Bromine Azidodithiocarbonate.** See Vol 1,p A635-R

**Bromine Chloride**, BrCl, mw 115.37; red-yel liq or gas, bp 10°(dec); according to Partington (Ref 2), Cl merely dissolves in liq Br and no compd(BrCl) has been obtd in the pure state, although from spectroscopic evidence BrCl appears to exist to some extent in a mixt of Cl & Br vapors. Hackh's(Ref 1) lists the compd as $BrCl.10H_2O$, yel crysts or liq, mp 7°(dec); v sol in w, $CS_2$ or eth. Sax(Ref 4) considers BrCl a very powerful oxidg agent which is dangerous when heated to decompn because it emits highly toxic fumes of Br & Cl; it is a mod fire hazard, reacting vigorously on contact with reducing materials. The physicochemical props of this and other interhalogen compds are reviewed by Greenwood(Ref 3)
*Refs:* 1)Hackh's(1944), 144 2)Partington(1950), 325 3)N.N.Greenwood, RevsPureAppliedChem (Australia) **1**, 84-120(1951) & CA **46**, 2356(1952) 4)Sax(1957), 383

**Bromine Dioxide.** See under Bromine Oxides

**Bromine Fluorides.** The following compds are described in the literature: *Bromine monofluoride*, BrF, mw 98.92, red-brn unstable gas, fr p -33°, bp 20°; is formed from the trifluoride & bromine (Ref 2). *Bromine trifluoride*, $BrF_3$, mw 136.92, col to gray-yel liq, fr p 8.8°, bp 135°, d 2.49 at 135°; is formed from fluorine and bromine or HBr (Ref 2). *Bromine pentafluoride*, $BrF_5$, mw 174.92, col liq, fr p -61.3°, bp 40.5°, d 2.47 at 25°, vap d 6.05; is formed from the elements at 0°(Ref 2). Sax(Ref 3) considers these compds to be dangerous when heated to decompn or on contact with an acid or acid fumes, since they emit highly toxic fumes of bromine & fluorine; they react with w or steam to produce heat, toxic and corrosive fumes

Sharpe & Emeléus(Ref 1) have studied the reaction of *bromine trifluoride*, with many metallic halides and other compds. These investigators found that $BrF_3$ reacts violently with KBr, KI & $CCl_4$ and explosively with acetone, dioxane, silicone vacuum grease, $NH_4F$ & $NH_4Cl$. An excess of $BrF_3$ converts the chlorides of K, Ag & Ba into the corresponding bromofluorides(bromotetrafluorides) $KBrF_4$, $AgBrF_4$ & $Ba(BrF_4)_2$. The *K compd* does not react with or dissolve in $CCl_4$, acet or dioxane, whereas the *Ag and Ba compds* do not react with $CCl_4$ but ignite eth, acet, dioxane & gasoline

*Refs:* 1)A.G.Sharpe & H.J.Emeléus, JCS **1948**, 2135-8 & CA **43**, 3739(1949) 2)Partington(1950), 341 3)Sax(1957), 384

**Bromine Hydrate**, $Br_2.10H_2O$, mw 340.0; red crysts, mp 6.8°(dec); is formed if satd bromine water is cooled in a freezing mixt in the presence of $Br_2$(Ref 4). The structure of this and other bromine hydrates has been the subject of many investigations. Hackh's(Ref 1) lists this compd as $Br.10H_2O$, red octahedric crysts, dec 15°; Stackelberg et al(Ref 2) and Partington(Ref 4) give $Br_2.8H_2O$; Claussen (Ref 5) and Müller & Stackelberg(Ref 7) give $Br_2.7^2/_3\ H_2O$; and Zernike et al(Ref 6) give the solid compd $Br_2.7H_2O$, mp 5.85°(dec).Stackelberg(Ref 3) has reviewed the structure, props, constitution, heat of form and other props of the gas hydrates. Sax(Ref 8) lists bromine hydrate ($Br_2.10H_2O$) as a strong oxidg agent which is dangerous when heated to decompn, emitting highly toxic fumes of bromine and, on contact with water or steam & reducing materials, it can react vigorously

*Refs:* 1)Hackh's(1944), 144 2)M.v.Stackelberg et al, FortschrMineral **26**, 122-4(1947)(publd in 1950) & CA **44**, 9846(1950) 3)M.v.Stackelberg, Naturwissenschaften **36**, 327-33 & 359-62(1949) & CA **44**, 7107(1950); with H.R.Müller, JChemPhys **19**, 1319-20(1951) & CA **46**, 4309(1952) 4) Partington(1950), 319 5)W.F.Claussen, JChemPhys **19**, 1425-6(1951) & CA **46**, 4309(1952) 6)J. Zernike et al, Rec **70**, 784-92(1951) & CA **46**, 8500(1952) 7)H.R.Müller & M.v.Stackelberg, Naturwissenschaften **39**, 20-1(1952) & CA **46**, 10998(1952) 8)Sax(1957), 383

**Bromine Oxides.** The following compds are described in the literature: *Bromine monoxide*, $Br_2O$, mw 175.83; dk-brn crysts, mp -17 to -18° (dec); can be prepd by the method of Schumacher & Townend(Ref 2) by passing bromine vapor over pptd HgO(Ref 3). *Bromine dioxide*, $BrO_2$, mw 111.92; lt-yel crysts, mp 0°(dec); prepd by the action of an elec discharge on a mixt of bromine vapor and excess O in a strongly cooled tube (Ref 3). Pflugmacher et al(Ref 4) detd the $Q_f$ of $BrO_2$ as -12.5 ± 0.7 kcal/mol from the reaction $BrO_2(solid) \longrightarrow 1/2Br_2 + O_2$. The $BrO_2$ was kept at -40°, where it was stable, and then transferred to a calorimeter at 20°, where it decomposed explosively. Pflugmacher(Ref 5) also obtd *trinitrobromine dioxide*, $BrO_2.3NO_2$, a wh solid stable up to -50°, which slowly decomposes at -40° to $BrO_2$ & $NO_2$ on passing a mixt of $O_2$, $N_2$ & $Br_2$ through a glow discharge at liq-air temp and low press or from $BrO_2$ and $NO_2$ at -40°. It decomps in w and bases, reacts with benz or eth and gives solns in $CHCl_3$ or acet stable up to -30°. *Bromine trioxide*, $BrO_3$, mw 127.92; wh crysts, mp dec above -70°; prepd by the reaction of $Br_2$ with a 50-fold excess of $O_2$ in a glow discharge at 0°(Ref 6). It gave col aq solns contg $BrO_3^-$; solns in MeOH or acet were also col at first, then turned yel or red on heating above -80°. The $BrO_3$ was sometimes produced mixed with $BrO_2$; addn compds may exist. *Bromine octaoxide*, $Br_3O_8$, mw 367.15; wh crysts, mp stable at -80°(Ref 3) to -40° (Refs 1 & 7); exists in two modifns with a transition point at -35°. It is prepd by the action of pure(100%) $O_3$ on purified Br vapor at -5 to +10° under low press(Ref 1). Only by keeping the temp of reaction low, carefully avoiding too much ozone or bromine, using very pure materials and a very clean appar can expln be avoided(Refs 1 & 3). This oxide is sol in w forming a col soln contg no free Br. It is unstable in the presence of $O_3$

Sax(Ref 7) considers the *bromine oxides* to be strong oxidg agents, representing mod fire hazard in the vapor state or by chem reaction with reducing materials. They are dangerous when heated to decompn, emitting highly toxic fumes of bromine

*Refs:* 1)B.Lewis & H.J.Schumacher, ZAnorgChem **182**, 182-6(1929) & CA **23**, 5426(1929) 2)H.J. Schumacher & R.V.Townend, ZPhysChem(Leipzig) **20B**, 375(1933) & CA **27**, 2881(1933) 3)Partington (1950), 323 4)A.Pflugmacher et al, ZAnorgChem **264**, 204-8(1951) & CA **47**, 6752-3(1953) 5)A. Pflugmacher, ZAnorgChem **273**, 41-7(1953) & CA **48**, 489(1954) 6)A.Pflugmacher et al, ZAnorgChem **279**, 313-20(1955) & CA **49**, 14550 (1955) 7)Sax(1957), 383-4

**Bromine Trioxide.** See under Bromine Oxides

**Bromoacetone(BA)**(called Brompropanon or Bromaceton in Ger), $CH_2BrCOCH_3$, mw 136.99, col liq(when pure) with pungent odor, mp -54°, bp 136°, d 1.631 at 0°; readily sol in alc, acet+eth and other org solvs; diffc sol in w; its prepn and other props are given in Beil(Ref 1). According to Sax(Ref 3), this compd is probably toxic but its toxicity details are not known

Wachtel(Ref 2) lists bromoacetone as first used in July 1915 in a war gas, called *Martonite* (BA 80 + chloroacetone 20%) in Fr, *B-Stoff* in Ger and *BA* in USA. This compd is a powerful lachrymator. In sprays, it causes, in contact with the skin, painful blisters, which heal within a short time. A concn of 1.5 mg/m³ causes tears immediately, 2.8 mg/m³ causes fighting inefficiency, 560 mg/m³ is toxic and 3200 mg/m³ is a lethal concn after 10 min exposure. Protection against the lachrymatory effect is possible by well-fitted goggles. Detection of BA in the field is easily made by odor & irritation caused by the vapor(Ref 2)

*Refs:* 1)Beil **1**, 657, (345) & [719] 2)Wachtel (1941), 142 & 172-4 3)Sax(1957), 384

**Bromoacetylene**(Bromoethyne), CH:CBr; mw 104.9, gas, with an unpleasant odor, bp -2°, vapor d 4.684; sl sol in w or dil $HNO_3$; can be prepd by methods given in Beil(Ref 1). The toxicity details of this gas are unknown(Ref 4). It ignites and expl on contact with air or O but ignition can be inhibited by the addn of $CS_2$, $C_2H_4$ or $SO_2$(Ref 3)

Bromoacetylene forms some expl salts, such as *Mercuri-monobromoacetylenide*, $Hg(C:CBr)_2$, wh plates(from chlf), expl mildly at 153-5°, expl on rubbing against clay; was prepd by Hofmann & Kirmreuther(Ref 2)

*Refs:* 1)Beil **1**, 245 & (106) 2)K.Hofmann & H. Kirmreuther, Ber **42**, 4235(1909) 3)H.J.Emeléus & H.V.A.Briscoe, JCS **1938**, 1358-64 & CA **33**, 531(1939) 4)Sax(1957), 385

**Bromoaminomethylbenzene.** See Bromomethyl-aniline

**Bromoaminotoluene.** See under Bromomethyl-aniline and Derivatives

### Bromoaniline and Derivatives

**Bromoaniline**(called Bromanilin in Ger), $Br.C_6H_4.NH_2$; mw 172.04, N 8.15%. Three isomers are described in the literature: *2-Bromoaniline*, crysts, mp 32°(Ref 1); *3-Bromoaniline*, crysts, mp 16.8°(Ref 2); *4-Bromoaniline*, mdls, mp 66°(Ref 3). All of these isomers form numerous salts & addn compds, some of which are unstable and even explosive when heated. Other props and methods of prepn are given in the Refs

*Refs:* 1)Beil **12**, 631, (313) & [341] 2)Beil **12**, 633, (315) & [342] 3)Beil **12**, 636, (317) & [344]

**Mononitrobromoaniline**, $(O_2N)Br.C_6H_3.NH_2$; mw 217.91%. Seven isomers are described in the literature: *4-Nitro-2-bromo-aniline*, yel ndls, mp 104.5; *4-Nitro-3-bromoaniline*, crysts(from alc), mp 175-6°; *2-Nitro-4-bromoaniline*, orn-yel ndls(from boiling w), mp 111.5°; *3-Nitro-4-bromoaniline*, flat ndls (from alc), mp 131°; *2-Nitro-5-bromoaniline*, red-yel ndls, mp 151-2°; *2-Nitro-6-bromoaniline*, yel ndls(from dil alc), mp 73-5°; and *3-Nitro-6-bromoaniline*, yel ndls (from alc), mp 141°. Some of these isomers form salts & addn compds, some of which are volatile and unstable.

Other props & methods of prepn are given in the

*Ref:* Beil **12**,737,738,739,(358) & [401,402,403]

**Dinitrobromoaniline**, $(O_2N)_2Br.C_6H_2.NH_2$; mw 262.03, N 16.04%. Eight isomers are described in the literature: *2,3-Dinitro-4-bromoaniline*, crysts, mp 158°; *2,3-Dinitro-6-bromoaniline*, dk-red crysts(from alc), mp 158°; *2,4-Dinitro-5-bromoaniline*, lt yld ndls mp 178°; *2,4-Dinitro-6-bromoaniline*, yel ndls(from AcOH or alc), mp 153-4°; *2,5-Dinitro-4-bromoaniline*, yel crysts (from alc), mp 186°; *2,6-Dinitro-4-bromoaniline*, orn ndls(from alc), mp 160-3°; *3,4-Dinitro-6-bromoaniline*, lt-yel crysts(from alc), mp 186°; and *3,5-Dinitro-2-bromoaniline*, golden-yel lfts (from alc), mp 180-1°. Other props & methods are given in the Ref. These compds are weak explosives. Compare with props of Dinitroanilines, Vol 1,p A408-L

*Ref:* Beil **12**,760,761,762,(367) & [417,418]

*Trinitrobromoaniline*, $(O_2N)_3BrC_6H.NH_2$; not found in Beil or in CA thru 1956

*Tetranitrobromoaniline*, $(O_2N)_4BrC_6.NH_2$; not found in Beil or in CA thru 1956

**Bromoazide.** See Bromine Azide under Azides, Vol 1,p A525-R

### Bromoazobenzene and Derivatives

**Bromoazobenzene**(called Bromazobenzol in Ger),

$BrC_6H_4.N:N.C_6H_5$; mw 261.13, N 10.7%. Three isomers are described in the literature: *2-Bromoazobenzene*, mp 87°(Ref 1): *3-Bromoazobenzene*, yel-brn lfts(from petr eth), mp 69°, volatilizes w/o decompn; sol in alc, eth, petr eth, chlf or benz(Ref 2) and *4-Bromoazobenzene*, orn-red pltlts, ref flakes(from alc) or orn colored lfts (from dil AcOH, mp 88-9°(Ref 3). Methods of prepn & other props are given in the Refs. Sax (Ref 4) states that the toxicity of the para-isomer is unknown but it is used as an insecticide

*Refs:* 1)Beil **16**, 40 & [41] 2)Beil **16**, 41 3)Beil **16**, 42, (223) & [14] 4)Sax(1957), 385

**Mononitrobromoazobenzene**, $C_{12}H_8N_2Br(NO_2)$; mw 306.12, N 13.7%. Four isomers are listed in Beil: *x-Nitro-3-bromoazobenzens*, orn-red ndls, mp 123°; *x-Nitro-4-bromoazobenzene*, yel ndls, mp 107-8°; *2-Nitro-4'-bromoazobenzene*, brick-red lfts with a golden-grn shimmer, mp 152.5°; and *4-Nitro-4'-bromoazobenzene*, dk-red crysts(from benz), mp 203°. Methods of prepn & other props are given in Beil

*Ref:* Beil **16**,41,42,51,(226) & [17]

**Dinitrobromoazobenzene**, $C_{12}H_7N_2Br(NO_2)_2$; mw 351.13, N 16.0%. Two isomers are listed in Beil: *x,x-Dinitro-4-bromoazobenzene*, ndls, mp 190° and *2,4-Dinitro-4'-bromoazobenzene*, red ndls, mp 175°. Other props & methods of prepn are given in the Ref

*Ref:* Beil **16**, 42 & 58

**Trinitrobromoazobenzene**, $C_{12}H_6N_2Br(NO_2)_3$; mw 396.13, N 17.7%. Only one isomer is described in the literature: *2,4,6-Trinitro-4'-bromoazobenzene*, red ndls(from alc), mp 170.5°; was prepd either by bromination of 2,4,6-trinitro-hydrazobenzene or oxidn of 4'-bromo-2,4,6-trinitrohydrazobenzene with chromic acid & AcOH(Refs 1 & 2). Its expl props were not detd

*Refs:* 1)Beil **16**, 59 2)C.Willgerodt & L.Elton, JPrChem **44**, 71(1891) & JCS **60** II, 1361-2(1891)

*Note:* Higher nitro derivs of bromoazobenzene were not found in Beil or in CA thru 1956

### Bromoazoxybenzene and Derivatives

**Bromoazoxybenzene**(called Bromazoxybenzol in Ger), $BrC_6H_4(N_2O)C_6H_5$; 277.13, N 10.1%. Two forms of the *4-Bromoazoxybenzene* are described in the literature: the α or low-melting form, straw-yel ndls(from alc), mp 73° and β or high-melting form, yel crysts(from petr eth), mp 93°. Prepn & other props are given in Beil

*Ref:* Beil **16**, (377) & [315]

**Mononitrobromoazoxybenzene**, $C_{12}H_8(N_2O)Br.NO_2$; mw 322.12, N 13.0%. Three isomers are listed in Beil: *4'-Nitro-4-bromoazoxybenzene* occurs as α- or low-melting form, crysts(from alc), mp 194° and β- or high-melting form, lt-yel prisms (from alc), mp 203°(Ref 1); *2-Nitro-4-bromoazoxybenzene*, yel ndls(from petr eth), mp 99° (Ref 2); and *4-Nitro-2-bromoazoxybenzene*, yel crysts(from alc), mp 127° or yel ndls(from benz), mp 135-7°(Ref 3). Methods of prepn & other props are given in the Refs

*Refs:* 1)Beil **16**, (378) & [317] 2)Beil **16**, (378) 3)Beil **16**, (379) & [318]

**Dinitrobromoazoxybenzene**, $C_{12}H_7(N_2O)Br(NO_2)_2$; mw 367.13, N 15.3%. Only one isomer is listed in Beil: *2,6-Dinitro-4-bromoazoxybenzene*, lt-yel ndls(from AcOH), mp 163°; prepn & other props are given in the Ref

*Ref:* Beil **16**, (379)

**Trinitrobromoazoxybenzene**, $C_{12}H_6(N_2O)Br(NO_2)_3$; mw 412.13, N 17.0%. Only one isomer is described in the literature: *2,6,3'(?)-trinitro-4-bromoazoxybenzene*, yel-grn crysts(from benz), mp 209°(dec); diffc sol in alc; was prepd by heating 4-bromo-2-nitroazoxybenzene with $HNO_3$(d 1.52) on a w bath(Refs 1 & 2)

*Refs:* 1)Beil **16**, (379) 2)B.Valori, AttiAccad-LinceiRend [5] **22** II, 133(1913) & JCS **104** I, 1110(1913)

*Note:* Higher nitro derivs of bromoazoxybenzene were not found in Beil or in CA thru 1956

**Bromobenzazimidol.** See Bromobenzohydroxy-triazole

### Bromobenzene and Derivatives

**Bromobenzene** *or Phenyl Bromide*(called Brombenzol in Ger), $C_6H_5.Br$; mw 157.02, clear, col, mobile liq, fr p -30.7°, bp 156.2°, flash p 149°F(closed cup), d 1.497, vap press 10mm at 40°, vap d 5.41; prepn & other props are given in Beil(Ref 1). Sax(Ref 2) lists this compd as mod toxic & mod dangerous when exposed to heat or flame

*Refs:* 1)Beil **5**, 206, (113) & [158] 2)Sax(1957), 385

**Azidobromobenzene**, $C_6H_4.Br(N_3)$; mw 198.03, N 21.22%. The following compds are described in the literature: *1-Azido-2-bromobenzene*, vol with steam; *1-Azido-3-bromobenzene*, bp 99° at 10mm; and *1-Azido-4-bromobenzene*, lfts, mp 20°, bp 105° at 10mm. Prepn & other props of these azido derivs are given in the Ref

*Ref:* Beil **5**, 277, (142) & [208]

**Azidonitrobromobenzene**, $O_2N.C_6H_3.Br(N_3)$; mw 243.03, N 23.06%. Three isomers are described

in the literature: *1-Azido-2-nitro-4-bromobenzene,* almost col ndls(from benz + pert eth), mp 80°:, readily sol in benz or acet, sol in MeOH or ethyl alc, v sl sol in petr eth(Refs 1 & 2); *1-Azido-2-nitro-5-bromobenzene,* yel pltls or prisms(from petr eth), mp 66°, readily sol in benz, acet or eth acet(Refs 1 & 2): and *1-Azido-3-nitro-6-bromobenzene,* straw-yel ndls(from alc), mp 58°(Ref 3). All derivs were prepd by diazotizing the appropriate bromonitroaniline with $NaNO_2$ and adding $NaN_3$. All of these derivs yield, on heating to 110°, bromobenzofuroxan(Refs 1,2 & 3)

*Refs:* 1)Beil **5**, (143) 2)M.O.Forster & M.F. Barker, JCS **103** II, 1920-1(1913) 3)G.Tappi & P.V.Forni, AnnChimApplicata **39**, 338-43(1949) & CA **46**, 2540(1952)

*Diazido bromobenzene,* $C_6H_3Br(N_3)_2$, and *Triazido bromobenzene,* $C_6H_2Br(N_3)_3$, not found in Beil or in CA thru 1956

**Nitrosobromobenzene,** $ON.C_6H_4.Br$; mw 186.02, N 7.53%. Three isomers exist and are described in the literature: *1-Nitroso-2-bromobenzene,* col ndls, mp 97.5-98°; *1-Nitroso-3-bromobenzene,* crysts, mp 78°; and *1-Nitroso-4-bromobenzene,* col ndls(from alc), mp 95°. Other props & methods of prepn are given in Beil

*Ref:* Beil **5**, 232, (124) & [171]

**Mononitrobromobenzene,** $O_2N.C_6H_4.Br$; mw 202.02, N 6.94%. Three isomers are described in the literature: *1-Nitro-2-bromobenzene,* lt yel slender ndls, mp 38-45°; *1-Nitro-3-bromobenzene,* exists in unstable form, mp 17.5° & in stable form as rhomb prisms, mp 54-6°; and *1-Nitro-4-bromobenzene,* triclinic prisms, mp 125-7°, explodes on heating to 755°. The prepn & other props are given in the Ref

*Ref:* Beil **5**, 247-8, (131-2) & [188]

**1-Nitroso-4-nitro-2-bromobenzene,** $O_2N.C_6H_3(NO).Br$; mw 231.02, N 12.13%; lt yel crysts(from alc), mp 123°, giving a grn liq; was prepd by treating 2,4-nitrobromoaniline with aq $K_2SO_4$ soln & concd $H_2SO_4$ and distilling the filtrate. Its expl props were not detd

*Refs:* 1)Beil-not found 2)D.Bigiavi et al, Gazz **61**, 392-6(1931) & CA **26**, 120(1932)

**Dinitrobromobenzene,** $(O_2N)_2C_6H_3.Br$; mw 247.02, N 11.34%. The following isomers are described in the literature: *1,3-Dinitro-2-bromobenzene,* yel prisms(from alc), mp 107° [Ref, p(138)]; *1,4-Dinitro-2-bromobenzene,* ndls (from alc) or prisms (from alc + eth), mp 70° [Ref,p(139)]; *1,2-Dinitro-3-bromobenzene,* yel pltls(from alc), mp 101.5° [Ref,p 266 & (138)]; *1,2-Dinitro-4-bromobenzene,* exists in unstable form, mp 34.8° & in stable form as ndls(from alc) or pltls(from alc + eth), mp 59.5°(Ref); and *1,3-Dinitro-4-bromobenzene,* yel crysts(from alc), mp 75.3° [Ref,p 266 & (138)]. The prepn & other props of these derivs are given in the Ref

*Ref:* Beil **5**, 266, (138-9) & [201]

**4-Nitroso-1,3-Dinitro-5-bromobenzene,** $(O_2N)_2C_6H_2(NO)Br$; mw 276.02, N 15.22%; dk-yel crysts(from AcOH), mp ca 99° giving a grn liq; sol in AcOH giving a dk grn color; was prepd by oxidg β-(6-bromo-2,4-dinitrophenyl)-hydroxylamine with chromic acid. Its expl props were not detd

*Ref:* Beil **5**, [203]

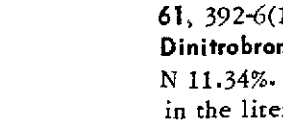
**Trinitrobromobenzene,** $(O_2N)_3C_6H_2.Br$; mw 292.02, N 14.39%. Three isomers are described in the literature: *1,2,4-Trinitro-5-bromobenzene,* ndls(from alc), mp 120-1°; readily sol in alc, eth, benz, acet or chlf; sl sol in petr eth; was obtd as the chief product from the nitration of 1,2-dinitro-4-bromobenzene(Refs 1 & 3); *1,2,4-Trinitro-6-bromobenzene,* yel crysts(from alc or AcOH), mp 101°; was prepd by nitrating 6-bromo-2,4-dinitropheylhydroxylamine with 2ps $HNO_3$(Refs 1 & 5); and *1,3,5-Trinitro-2-bromobenzene or Picryl Bromide,* yel-wh pltls(from alc), mp 122-3°; was prepd by nitrating 1,3-dinitro-4-bromobenzene(Refs 2 & 4). These isomers are all expl compds although their expl props were not reported

*Refs:* 1)Beil **5**, [206-207] 2)Beil **5**, 275 & [207] 3)M.Giua, Gazz **51** I, 309(1921) & JCS **120** I, 551(1921) 4)A.H.Rheinlander, JCS **123** II, 3110(1923) 5)W.Borsche & E.Feske, Ber **59**, 685(1926) & CA **20**, 2666(1926)

*Note:* Higher nitro derivs of bromobenzene were not found in Beil or in CA thru 1956

## Bromobenzohydroxytriazole and Derivatives

**Bromobenzohydroxytriazole or Bromobenzazimidol,** $Br.C_6H_4N_3O$; mw 214.03, N 19.64%. Two isomers are described in the literature: *5-Bromobenzo-1-hydroxy-α-vic-triazole* [called 1-Bromobenzo-3,4(3'-azimidole) by Mangini(Ref 2)],



; hex prisms(from alc), mp 201.5-2.5°(expl decompn); was prepd by boiling an alc suspension of $2,5\text{-}O_2N(Br)C_6H_3NH.NH_2$ with 5% alc KOH and acidifying the reaction mixt(Ref 2); and *6-Bromobenzo-1-hydroxy-α-vic-triazole* [called 1-Bromobenzo-3,4-(1'-azimidole) by Mangini(Ref 2) and 1-Oxy-6-brom-benztriazol or 6-Brom-benzazimidol in Ger(Ref 1)],

Br.C-CH=C-N(OH)
‖ | >N ; col prisms(alc + HCl), mp
HC-CH=C-N
188-96°(decompn); was prepd by heating 2,5-dibromo-1-nitrobenzene with an excess of hydrazinehydrate in dil alc(Refs 1,2 & 3)
*Refs:* 1)Beil **26**, [26] 2)A.Mangini, Gazz **66**, 675-84(1936) & CA **31**, 4961(1937) 3)S.S.Joshi & D.S.Deorha, JIndianChemSoc **29**, 545-8(1952) & CA **47**, 8738-9(1953)

**Mononitrobromobenzohydroxytriazole or Mononitrobromobenzazimidol**, $Br.C_6H_3(NO_2)N_3O$; mw 259.03, N 21.63%. Two isomers are described in the literature: *4-Bromo-6-nitro-1-hydroxy-a-vic-triazole*, lt orn-brn crysts, mp 205°; and *6-Bromo-4-nitro-1-hydroxy-a-vic-triazole*, yel crysts, mp 208°. These and other substituted derivs of benzazimidole were prepd from chloronitrobenzene and hydrazine or substituted hydrazine(Ref 2)
*Refs:* 1)Beil-not found 2)S.S.Joshi & D.S. Deorha, JIndianChemSoc **29**, 545-8(1952) & CA **47**, 8738(1953)
*Note:* Higher bromonitro derivs were not found in Beil or in CA thru 1956. See chloro, dichloro & other derivs under Benzotriazolol and Derivatives, p B88

## Bromobenzoquinone and Derivatives

**Bromobenzoquinone**(called Brom-benzochinon or Bromchinon in Ger), $O:C_6H_3(Br):O$; mw 187.00. Only the *2-Bromo-1,4-benzoquinone* is known, orn-yel crysts(from petr eth), mp 56.5°, sublimes when carefully heated; other props & methods of prepn are given in the Refs
*Refs:* 1)Beil **7**, 639 & [583] 2)A.N.Grinev & A.P. Terent'ev, ZhObshchKhim **25**, 2145-6(1955) & CA **50**, 8509(1956) 3)P.Souchay et al, JPhysRadium **15**, 533-5(1954) & CA **50**, 9879(1956)(IR absorption spectrum)

**2-Diazo-3-bromo-o-benzoquinone** [called 3-Brom-2-diazo-phenol or 3-Brom-o-chinon-diazid-(2) in Ger], $O:C_6H_3(Br):N_2$; mw 199.02, N 14.08%; orn col prisms(from eth), mp 103°(dec), v sensitive to light; was prepd by treating 2,6-dibromobenzenediazonium sulfate with aq Na acetate soln for 4 days(Refs 1 & 2)
*Refs:* 1)Beil **16**, 523 2)K.J.P.Orton, JCS **83**, 812(1903)

**Mononitrodiazobromobenzoquinone**, $O:C_6H_2(NO_2)(Br):N_2$; mw 244.02, N 17.22%. Three isomers are described in the literature: *2-Diazo-4-nitro-6-bromo-1,2-benzoquinone* [called 6-Brom-4-nitro-2-diazo-phenol or 6-Brom-4-nitro-o-chinon-diazid (2) in Ger], yel ndls(from w), dec ca 152-3°; was prepd by adding $NaNO_2$ soln to the HCl of 6-bromo-4-nitro-2-aminophenol(Refs 1 & 2); *2-Diazo-6-nitro-4-bromo-1,2-benzoquinone* [called 4-Brom-6-nitro-2-diazo-phenol or 5-Brom-3-nitro-o-chinon-diazid-(1) in Ger], brn ndls having greenish metallic luster, mp explodes with extreme violence at ca 144°; was prepd by adding $NaNO_2$ soln to the HCl of 4-bromo-6-nitro-2-aminophenol(Refs 1 & 3); and *4-Diazo-2-nitro-5-bromo-1,4-benzoquinone* (called 5-Brom-2-nitro-1,4-quinone azide in CA), yel-brn crysts, mp 186°(dec & explodes); was prepd by bromination of 2,3,5-trinitro-4-amino-phenol(Ref 4)
*Refs:* 1)Beil **16**, 524 2)R.Meldola et al, JCS **69** II, 1327(1896) 3)R.Meldola & F.H.Streatfield, JCS **73**, 688(1898) 4)G.Heller et al, JPraktChem **129**, 217 & 241(1931); CA **25**, 2129(1931) & BrA **1931A**, 478

**2-Bromo-1,4-benzoquinone-1-oxime** [called 2-Brom-p-chinon-oxim-(1) in Ger], $O:C_6H_3(Br):N.OH$; mw 202.02, N 6.9%; pale greenish crysts(from benz), mp 190-6°; other props & methods of prepn are given in the Ref
*Ref:* Beil **7**, [583]

**2-Bromo-1,4-benzoquinone-4-oxime** [called 2-Brom-p-chinon-oxim-(4) or 2-Brom-4-nitroso-phenol in Ger], $O:C_6H_3(Br):N.OH$ or $HO.C_6H_3(Br).NO$. See 4-Nitroso-2-bromophenol under Bromophenol and Derivatives

**2-Bromo-1,4-benzoquinone-4-methylimine-1-oxime** [called 2-Brom-p-chinon-methylimid-(4)-oxim-(1) or 3-Brom-4-nitroso-methylanilin in Ger], $H_3C.N:C_6H_3(Br):N.OH$ or $H_3C.HN.C_6H_3(Br).NO$. See *4-Nitroso-3-bromomethylaniline* under Bromomethylaniline and Derivatives or 3-Bromo-1,4-benzoquinone-1-methylimine-4-oxime under Benzoquinone Oxime and Derivatives

## Bromobenzoyl Azide and Derivatives

**Bromobenzoyl Azide**(called Brom-benzazid in Ger), $Br.C_6H_4.CO.N_3$; mw 226.03, N 18.59%. Three isomers are described in the literature: *2-Bromobenzoyl Azide.* Prepn & props given in Ref 3, which was not available for review; *3-Bromobenzoyl Azide*, col oil having disagreeable odor and producing tears; mp expl violently on heating; readily sol in alc, eth, acet or chlf; insol in w; was prepd by the action of nitrous acid on 3-bromobenzhydrazide(Refs 1,p 351 & 2,p 195) *4-Bromobenzoyl Azide*, col plates(from acet), mp 46°, expl at higher temps; readily sol in alc, acet or eth; insol in w; was prepd by the action of nitrous acid on 4-bromobenzhydrazide(Refs 1,p

355 & 2,p 201)
*Refs:* 1)Beil **9**, 351 & 355 2)T.Curtius & E. Portner, JPraktChem **58**, 195 & 201(1898) & JCS **76** I, 136(1899) 3)P.P.T.Sah et al, JChineseChemSoc **13**, 22-76(1946) & CA **42**, 148(1948)(Describes the use of these compds as reagents for identification of alcohols, amines & phenols)
*Mononitrobromobenzoyl Azide,* $Br.C_6H_3(NO_2).CO.N_3$; not found in Beil or in CA thru 1956
**Dinitrobromobenzoyl Azide,** $Br.C_6H_2(NO_2)_2.CO.N_3$; mw 316.05, N 22.16%. Two isomers are described in the literature: *3,5-Dinitro-2-bromobenzoyl Azide,* yel crysts, mp 67°(dec); was prepd by conversion of the corresponding chloride in glac and AcOH by reaction with Na azide(Ref 1,p 997) and
*3,5-Dinitro-4-bromobenzoyl Azide,* col fine ndls (from petr eth), mp 116°; was prepd by addn of Na azide to 4-bromo-3,5-dinitrobenzoyl chloride suspended in glac AcOH. Although its expl props were not investigated this compd is an expl. Compare with the props of 3,5-dinitrobenzoyl azide under Benzoyl Azide and Derivatives(Ref 2,p 991)
*Refs:* 1)Beil-not found 2)J.J.Blanksma & G. Verberg, Rec **53**, 991 & 997(1934) & CA **29**, 462 (1935)
*Trinitrobromobenzoyl Azide,* $Br.C_6H(NO_2)_3.CO.N_3$; not found in Beil or in CA thru 1956

**Bromobenzoyl Azidodithiocarbonate.** See Vol 1,p A633-L under Azidodithiocarbonic Acid and Derivatives

**N-(4-Bromo-2,4-dinitrophenyl)-N-nitro-β-aminoethyl Nitrate.** See 2,4-Dinitro-4-bromophenylnitraminoethyl Nitrate to be described under Phenylaminoethanol and Derivatives

**N-(5-Bromo-2,4-dinitrophenyl)-N-nitro-β-aminoethyl Nitrate.** See 2,4-Dinitro-5-bromophenylnitraminoethyl Nitrate to be described under Phenylaminoethanol and Derivatives

## Bromoethane and Derivatives

**Bromoethane, Ethyl Bromide,** *Bromic Ether or Hydrobromic Ether*(called Bromäthan or Äthylbromid in Ger), $CH_3.CH_2.Br$; mw 108.98; col vol liq, fr p -119°, bp 38.4°, d 1.430 at 20°; vap press 400mm at 21°C; prepn & other props are given in Beil(Ref 1). Sax(Ref 2) lists this compd as an anesthetic & narcotic. It readily dec into vol toxic products which are markedly irritating to the lungs and can produce acute congestion & endema. It is much less toxic than methyl bromide, but more toxic than ethyl chloride
*Refs:* 1)Beil **1**, 88, (26), & [59] 2)Sax(1957), 668
**1-Azido-2-bromoethane,** $N_3.CH_2.CH_2.Br$; mw 149.99, N 28.02%; col liq, having an odor of ethylene dibromide & rapidly becoming yel when exposed to light, bp 49° at 20mm, d 1.6675 at 19°; does not ignite when thrown on a hot plate but merely crackles; was prepd from β-azidoethanol by the action of $PBr_3$(phosphorus tribromide) in petr eth(Refs 1 & 2)
*Refs:* 1)Beil **1**, (33) 2)M.O.Forster & S.H. Newman, JCS **97** II, 2571-7(1910)
**1-Nitro-1-bromoethane,** $O_2N.BrCH.CH_3$; mw 153.97, N 9.09%; vol liq boiling at 146-7° w/o decompn; insol on w; prepn & other props are given in Beil
*Ref:* 1)Beil **1**, 101 & (32)
**1,1-Dinitro-1-bromoethane,** $(O_2N)_2Br.C.CH_3$; mw 198.98, N 14.62%; oily liq, vol with steam; dec on heating, with bromine splitting off; somewhat sol in w; prepn & other props are given in Beil. Its expl props were not reported
*Ref:* Beil **1**, 102 & [70]
*Note:* Higher nitro derivs of bromoethane were not found in Beil or in CA thru 1956

## Bromoethanol and Derivatives

**2-Bromoethanol** [called 2-Bromäthanol-(1), β-Brom-äthylalkohol, Äthylenbromhydrin or Glykolbromhydrin in Ger], $Br.CH_2.CH_2.OH$; mw 124.98; col hygr liq, dec on distilling at atm press, bp ca 148° with partial decompn, bp 56-7° at 20mm, d 1.7494 at 30°; other props & methods of prepn are given in Ref
*Ref:* Beil **1**, 338, (170) & [337]
**2-Bromoethylnitrate,** $Br.CH_2.CH_2.ONO_2$; mw 169.98, N 8.2%; oily liq, bp beginning at 132° with a portion at 163-5°, d 1.78; was prepd from ethylene, bromine & $NaNO_3$ soln. Before distillation the oil was washed with $NaHCO_3$ to remove any trace of $HNO_3$. In the distillation the last trace exploded with the evolution of brn nitrous fumes(Refs 1 & 2)
*Refs:* 1)Beil **1**, 339 & [338] 2)A.W.Francis, JACS **47**, 2347(1925)
**2-Nitro-2-bromoethylnitrate,** $Br.CH(NO_2).CH_2.ONO_2$; mw 215.02, N 13.05%; viscous yel liq, d 2.438 at 11°; was prepd by treating 2-bromo-2-nitroethanol with a mixt of nitric & sulfuric acids (Refs 1 & 2). The chloro deriv detonates on

rapid heating; Ref 1,p [340]
*Refs:* 1)Beil **1**, 340 & [340] 2)J.Maas, Rec **17**, 389(1898) & JCS **76 I**, 322(1899)

**2-Nitro-2-bromoethanol**, $Br.CH(NO_2).CH_2.OH$; mw 169.98, N 8.2%; thick yel liq having a pungent odor, bp 147-8° at 45mm, d 2.084 at 10°; sol in alc or eth; sl sol in w; was prepd by the condensation of bromonitromethane with formaldehyde in the presence of K carbonate and by other methods(Refs 1 & 2)

Its K(Ref 4) & Na(Ref 3) salts were prepd, the corresponding chloro derivs of which expl on heating in a flame
*Refs:* 1)Beil **1**, 339 & [340] 2)J.Maas, Rec **17**, 386(1898) & JCS **76** I, 322(1899) 3)R.Wilkendorf & M.Trénel, Ber **56**, 611(1923) & CA **17**, 2414-5 (1923) 4)M.Trénel & R.Wilkendorf, Ber **57**, 2126 (1924) & CA **19**, 1406(1925)
*Note:* Higher nitro derivs of bromoethanol were not found in Beil or in CA thru 1956

### Bromoform and Derivatives

**Bromoform or Tribromomethane**(called Bromoform, Methenylbromid or Tribrommethan in Ger), $CHBr_3$; mw 252.77, col liq or hex crysts, mp 6-7°, bp 149.5°, d 2.890 at 20°. Other props & its method of prepn are given in Beil(Ref 1)

According to Sax(Ref 2), bromoform has anesthetic props similar to those of chloroform but it is too toxic to be recommended for this purpose. The inhalation of small amts causes irritation, flow of tears & reddening of the face. In addn to its narcotic effects, it is a metabolic poison. It can damage the liver to a serious degree & cause death
*Refs:* 1)Beil **1**, 68, (16) & [33] 2)Sax(1957), 387-8

**Nitrobromoform, Bromopicrin or Tribromonitromethane**, $O_2N.C.Br_3$; mw 297.78, N 4.71%; prismatic crysts having a strong odor, mp ca 10.3°, bp 127° at 118mm & 85° at 17mm; expl on heating at atm pressure evolving a red-brn vapor; d 2.781 at 20°; other props & methods of prepn are given in Beil(Ref 1)

Ogilivie et al(Ref 4) found that bromopicrin, choloropicrin, Br & other compds caused an increase in the knocking tendency in aviation gasoline. These compds counteracted the effect of antiknock additives & also had some effect on the base stock fuel

A method for determining the quantity of bromopicrin & certain other poisons or vesicants by reaction with sulfhydryl(-SH) substances was reported by Fischer(Ref 3)
*Refs:* 1)Beil **1**, 77, (21) & [43] 2)Vivas, Feigenspan & Ladreda, Vol 2(1946), 21 3)P. Fischer, JPharmBelg [NS] **2**, 225-9(1947) & CA **42**, 699(1948) 4)J.D.B.Ogilvie et al, CanJRes **26F**, 246-63(1948) & CA **42**, 7967(1948) 5)Sax (1957), 387

**Bromoformamidine Nitrate.** See under Formamidine and Derivatives

**Bromoformamidine Perchlorate.** See under Formamidine and Derivatives

### Bromomethane and Derivatives

**Bromomethane or Methylbromide**(called Brommethan or Methylbromid in Ger), $CH_3.Br$; mw 94.95; col transparent vol gas or liq, fr p -93°, bp 3.56°, autoign temp 998°F, vap d 3.27; other props & methods of prepn are given in Beil(Ref 1)

According to Sax(Ref 2), bromomethane is 8 times more toxic on inhalation than bromoethane. Its MAC(max allowable concn) is 20ppm in air or 78mg/m³. Death following acute poisoning by bromomethane is usually caused by its irritant effect on the lungs. In chronic poisoning, death is due to injury to the central nervous system. Fatal poisoning has always resulted from exposure to relatively high concns of vapors (8600 to 60000 ppm). Locally, bromomethane is an extreme irritant to the skin and may produce severe burns
*Refs:* 1)Beil **1**, 66, (15) & [31] 2)Sax(1957), 883-4

*Mononitrobromomethane*, $CH_2Br.NO_2$; mw 139.96, N 10.01%; corrosive liq having a penetrating odor, fr p -28°, bp 152.5° at 765mm press; other props & methods of prepn are given in Beil
*Ref:* Beil **1**, 77, (21) & [43]

**Dinitrobromomethane**, $CHBr(NO_2)_2$; mw 184.96, N 15.15%. Its *K salt*, $K.C.Br(NO_2)_2$, triclinic yel crysts(from w), expl on heating to ca 145°; in aq soln with $AgNO_3$ yields the *Ag salt*, $Ag.C.Br(NO_2)_2$, yel expl ndls which become steel-blue in air. Other props & methods of prepn are given in the Refs
*Refs:* 1)Beil **1**, 78, (21) & [44] 2)M.Trénel & R. Wilkendorf, Ber **57B**, 2126(1924) & CA **19**, 1406 (1925)

**Trinitrobromomethane**, $Br.C(NO_2)_3$; mw 229.95, N 18.27%; clear liq with a faint grn-yel tinge, fr p 10-18°, bp 59° at 8mm & 68° at 20mm, at atm press decompn takes place, d 2.07 at 19°, $n_D$ 1.4900 at 19°; Raman & IR spectra have been reported by Mathieu & Massignon(Ref 3); was

prepd by the action of Br or HBr on nitroform (trinitromethane) in $HNO_3$ soln or K nitroform & Br in eth and by other methods(Refs 1 & 2). Its expl props were not reported

*Refs:* 1)Beil **1**, 79, (21) & [46] 2)A.K.Macbeth & D.D.Pratt, JCS **119** I, 356(1921) & **119** II, 1357 (1921) 3)J.P.Mathieu & D.Massignon, AnnPhys **16**, 5(1941); ChemZtr **1942** II 24 & CA **37**, 4304 (1943)

### Bromomethylaniline and Derivatives

**Bromomethylaniline, Bromoaminomethylbenzene,** *Bromoaminotoluene or Bromotoluidine*(called Brom-methylanilin or Brom-aminotoluol in Ger), $C_7H_8NBr$; mw 186.06, N 7.53%. The *Bromo-N-methylaniline,* isomers, $Br.C_6H_4.NH.CH_3$, are described in Ref 1 and the *Bromo-aminotoluene* isomers, $Br.C_6H_3NH_2.CH_3$, are described in Ref 2. Most of these compds are liquids or low-melting crysts. Many form salts & addn compds, some of which are unstable. Other props & methods of prepn are given in the Refs

*Refs:* 1)Beil **12**, 637, (317) & [341,345] 2)Beil **12**, 837,838,839,873,991, (389,390; 436) & [455, 456,474,532]

**Nitrosobromomethylaniline**, $C_7H_7N_2OBr$; mw 215.07, N 13.03%. The following isomers are described in the literature: *4-Nitroso-2-bromo-methylaniline* or *p-Quinone-1-methylimine-2-bromo-4-oxime,* $(ON)Br.C_6H_3.NH.CH_3$ or $HON:C_6H_3(Br):N.CH_3$, blue-grn crysts(from benz), mp 87°(Refs 1 & 6) & 104°(Refs 1 & 3); *4-Nitroso-3-bromomethylaniline or p-Quinone-1-methylimine-3-bromo-4-oxime,* grn crysts, mp turns dark at 100° & explodes at 124°; its *Hydrochloride salt,* red, turns yel at 140° & melts with decompn at 168°(Refs 1 & 4); *N-Nitroso-2-bromo-N-methylaniline or (2-Bromophenyl)-methylnitrosamine,* $Br.C_6H_4.N(NO).CH_3$, vol on steam bath(Refs 2 & 6); *N-Nitroso-3-bromo-N-methylaniline or (3-Bromophenyl)-methylnitrosamine,* yel ndls, mp 43-4°(Refs 2 & 5) & 49°(Refs 2 & 4); and *N-Nitroso-4-bromo-N-methylaniline or (4-Bromophenyl)-methylnitrosamine,* col ndls(from alc), mp 74-8°(Refs 2,3,5 & 6). Other props & methods of prepn are given in the Refs

*Refs:* 1)Beil **7**, (348) & [583,584] 2)Beil **12**, [342,343,354] 3)O.Fischer & P.Neber, Ber **45**, 1097, 1101(1912) & JCS **102** I, 438(1912) 4)M.S. Kharasch & J.F.Piccard, JACS **42**, 1858-9(1920) 5)E.Schmidt & R.Schumacher, Ber **54**, 1415-6 (1921) & JCS **120** I, 660(1921) 6)E.Votocek & R. Lukes, BullFr [4] **35**, 874, 879(1924) & JCS **126** I, 1120(1924)

**Mononitrobromomethylaniline**, $C_7H_7N_2O_2Br$; mw 231.07, N 12.12%. The *Mononitrobromo-N-methylaniline* isomers, $O_2N.C_6H_3Br.NH.CH_3$, are described in Ref 1 and the *Mononitrobromo-aminotoluene* isomers, $O_2N.C_6H_2(Br)NH_2.CH_3$, are described in Ref 2. All of the N-methylaniline isomers and all of the methylaniline isomers are colored crysts compds. Their props & methods of prepn are given in the Refs

*Refs:* 1)Beil **12**, 737, 738,739 & [401,402] 2)Beil **12**, 850,851,878,1007,(395,409,441) & [462,479]

**Mononitro-N-nitroso-bromethylaniline or Nitrobromophenyl-methylnitrosamine,** $O_2N.C_6H_3Br.N(NO).CH_3$; mw 260.06, N 16.16%. Two isomers are described in the literature: *2-Nitro-N-nitroso-4-bromo-N-methylaniline or (2-Nitro-4-bromophenyl)-methylnitrosamine,* crysts(from MeOH), mp 73°(Refs 1 & 2); and *3-Nitro-N-nitroso-4-bromo-N-methylaniline or (3-Nitro-4-bronophenyl)-methylnitrosoamine,* yel ndls(from MeOH), mp 78°(Refs 1 & 2). Other props & methods of prepn are given in the Refs

*Refs:* 1)Beil **12**, [401,402] 2)W.G.Macmillan & T.H.Reade, JCS **1929**, 2866

**Dinitrobromomethylaniline**, $C_7H_6N_3O_4Br$; mw 276.06 N 15.22%. Three N-methyl derivs, $(O_2N)_2C_6H_2Br.NH.CH_3$, are described in the lieerature: *2,4-Dinitro-5-bromo-N-methylaniline,* yel crysts(from alc), mp 149-150°; *2,4-Dinitro-6-bromo-N-methylaniline,* yel crysts(from AcOH), mp 147°; and *2,6-Dinitro-4-bromo-N-methylaniline,* orn ndls or yel crysts(from alc or petr eth), mp 104-6°(Ref 1). Two aminotoluene or methylaniline derivs, $(O_2N)_2C_6H(Br)NH_2.CH_3$, are described in the literature: *4,6-Dinitro-3-bromo-2-methylaniline,* yel crysts, mp 200°; and *3,5-Dinitro-2-bromo-4-methylaniline,* lt yel ndls or prisms (from alc), mp 170-4°(Ref 2). Other props & methods of prepn are given in the Refs

*Refs:* 1)Beil **12**, 761 & [417, 418] 2)Beil **12**, (397, 445) & [540]

**2,6-Dinitro-N-nitroso-4-bromo-N-methylaniline or 2,6-Dinitro-4-bromophenyl)-methylnitrosamine,** $(O_2N)_2C_6H_2Br.N(NO).CH_3$; mw 305.06, N 17.14%; lt-yel ndls(from alc), mp 124°; was prepd by treating 4-bromodimethylaniline with mixed $HNO_3$-$H_2SO_4$ below 40° or 2-nitro-4-bromo-dimethylaniline with 52% $HNO_3$ betw 10-35° (Refs 1 & 2). Its expl props were not detd

*Refs:* 1)Beil **12**, [419] 2)G.R.Clemo & J.M. Smith, JCS **1928**, 2421

**Trinitrobromomethylaniline,** $C_7H_5N_4O_6Br$; mw 321.06, N 17.45%. The following isomers are described in the literature: *N,2,4-Trinitro-6-bromo-N-methylaniline; 2,4-Dinitro-N-nitro-6-bromo-N-methylaniline or (2,4-Dinitro-6-bromophenyl)-methylnitramine,* $(O_2N)_2C_6H_2Br.N(NO_2).CH_3$, col crysts, mp 125°; was prepd by nitration of either 4-nitro-2-bromo-N-methylaniline or 2,4-dinitro-6-bromo-N-methylaniline(Refs 1 & 3); and *N,2,6-Trinitro-4-bromo-N-methylaniline; 2,6-Dinitro-N-nitro-4-bromo-N-methylaniline or (2,6-Dinitro-4-bromophenyl)-methylnitramine,* col crysts, mp 110° or lt yel ndls(from alc), mp 113-4°; was prepd by nitration of either 2-nitro-4-bromo-N-methylaniline or (2,6-dinitro-4-bromophenyl)-methylnitrosamine(Refs 2,3 & 4). These compds will defgr or expl when heated above their mp's, but their expl props were not detd

*Refs:* 1)Beil **12,** 761 2)Beil **12,** 762 & [419] 3)J.J.Blanksma, Rec **21,** 271-2(1902) 4)G.R. Cleo & J.M.Smith, JCS **1928,** 2421-2

**Tetranitrobromomethylaniline,** $C_7H_4N_5O_8Br$; mw 366.06, N 19.13%. Three isomers are described in the literature: *N,2,3,4-Tetranitro-6-bromo-N-methylaniline; 2,3,4-Trinitro-N-nitro-6-bromo-N-methylaniline or (2,3,4-Trinitro-6-bromophenyl)-methylnitramine,* $(O_2N)_3C_6HBr.N(NO_2).CH_3$, crysts, mp 116°; was prepd by nitration of 3,4-dinitro-6-bromodimethylaniline(Refs 2 & 4); *N,2,3,6-Tetranitro-4-bromo-N-methylaniline; 2,3,6-Trinitro-N-nitro-4-bromo-N-methylaniline or (2,3,6-Trinitro-4-bromophenyl)-methylnitramine,* lt-yel ndls(from alc), mp 158° [Forster & Coulson(Ref 4) give 165°]; was prepd by nitrating 3-nitro-4-bromodimethylaniline(Refs 2 & 5) or 2,5-dinitro-4-bromodimethylaniline or 2,3,6-trinitro-4-bromodimethylaniline(Refs 2 & 4); and *N,2,4,6-Tetranitro-3-bromo-N-methylaniline; 2,4,6-Trinitro-N-nitro-3-bromo-N-methylaniline or (2,4,6-Trinitro-3-bromophenyl)-methylnitramine,* col crysts(from chlf), mp 127°; was prepd by nitration of 2-nitro-5-bromo-N-methylaniline(Refs 1 & 3). These compds are expl, but their expl props were not detd

*Refs:* 1)Beil **12,** 771 2)Beil **12,** [427] 3)J.J. Blanksma, Rec **21,** 278(1902) 4)A.Forster & W.Coulson, JCS **121** II, 1955(1922) 5)G.R.Clemo & J.M.Smith, JCS **1928,** 2422

**Bromomethylbenzene.** See Bromotoluene

**N-Bromo-N'-methyl-ethylenedinitramine,** $Br.\underset{NO_2}{N}.CH_2.CH_2.\underset{NO_2}{N}.CH_3$; mw 243.05. N 23.05; OB to $CO_2$ -36.2%; pale yel crysts(from acet+w), mp 118-9°(dec); was prepd by addg liq Br to an aq KOH soln of N-methyl-ethylenedinitramine and stirring with subsequent cooling. The following expl props were reported: *Explosion Temperature,* no expln at 360° in 5 secs; *Impact Sensitivity* 6.6cm at 50% point(RDX=35cm); *Power* by Ballistic Mortar Test, 101% TNT; *Thermal Stability* by 135° Heat Test, sample ignited in 4mins

The dry compd is more stable than dry dibromo deriv. The N halogen derivs of aliphatic nitramines were prepd and studied for possible uses as tracer compds and in detonator compns. Attempts to prep the iodo derivs were unsuccessful because they are too unstable to be isolated and purified

*Refs:* 1)Beil & CA- not found 2)A.T. Blomquist, "Certain Aliphatic Nitramines and Related Compounds", OSRD Rpt **4134**(1944),pp 12-15, 69-70 & 86(PB No **18867**)

## Bromonicotinic Acid and Derivatives

**Bromonicotinic Acid** or *5-Bromopyridine-3-carboxylic Acid* [called 5-Brom-pyridin-carbonsäure-(3) or 5-Brom-nicotinsäure in Ger], $HC\overset{\alpha}{-}N=CH$ / $Br.C-CH=C.COOH$ ; mw 202.22, N 6.9%; lfts or prisms having 2 mols $H_2O$, loses w of crystn at 100°, mp 182-3°, sublimes w/o decompn; forms numerous inorg salts; other props & methods of prepn are given in Beil

*Ref:* Beil **22,** 44-5

**5-Bromo-nicotinyl Azide, 5-Bromo-3-pyridoyl Azide or Azido-5-bromonicotinic Acid,** $Br.C_5H_3N.CON_3$; mw 227.03, N 24.68%; col powdery ppt, mp 88-9°(decomp), burns w/o defgrn; was prepd by diazotizing the hydrazide in excess HCl. The hydrazide was prepd by refluxing the Me ester of 5-bromo-nicotinic acid in alc with hydrazine hydrate(Ref 2)

*Refs:* 1)Beil-not found 2)R.Graf et al, JPrakt-Chem **138,** 251(1933); BrA **1933A** & CA **28,** 769(1934)

*Note:* There were also prepd the hydrazine & hydrazide derivs of bromopyridine carboxylic acid. No nitro or nitrated derivs were found in Beil or in CA thru 1956

## Bromophenol and Derivatives

**Bromophenol**(called Bromphenol in Ger), $Br.C_6H_4.OH$; mw 163.02. Three isomers exist and are described in the literature:

*2-Bromophenol,* oil, having disagreeable odor, bp 194°; *3-Bromophenol,* lfts, mp 32-33°; and *4-Bromophenol,* crysts(from chlf or eth), mp 64°
*Ref:* Beil **6**, 197, 198, (104,105) & [183,184]

**Nitrosobromophenol,** (ON)Br.$C_6H_3$.OH; mw 202.02, N 6.94%. Two isomers are described in the literature: *4-Nitroso-2-bromophenol,* pale yel to lt-brn ndls(from benz or w) or red ndls (from dil alc), mp 142-56°(dec)(Refs 1 & 3) and *4-Nitroso-3-bromophenol* yel ndls(from eth + petr eth), mp 139°(dec)(Ref 2); absorption spectra (Ref 4). Other props & methods of prepn are given in the Refs
*Refs:* 1)Beil **7**, 639 & [583] 2)Beil **7**, [583] 3)H.H.Hodgson & D.E.Nicholson, JCS **1940**, 811 (1940) & CA **34**, 6590(1940) 4)P.Ramart-Lucas et al, BullFr **1948**, 571 & CA **42**, 7633(1948)

*Dinitrosobromophenol,* $(ON)_2BrC_6H_2$.OH, not found in Beil or in CA through 1956

**Mononitrobromophenol,** $(O_2N)$Br.$C_6H_3$.OH; mw 218.02, N 6.43%. Ten isomers are described in the literature(Ref 1). Their props & methods of prepn are given in the Ref
*Ref:* Beil **6**, 243,244,(123) & [232,233,234]

**Dinitrobromophenol,** $(O_2N)_2$Br.$C_6H_2$.OH; mw 263.02, N 10.65%. Four isomers are described in the literature: *2,4-Dinitro-3-bromophenol,* yel ndls(from w), mp 175°(Refs 1 & 6); *2,4-Dinitro-5-bromophenol,* col prisms(from alc or eth), mp 91.5-92°(Refs 2 & 6); *2,4-Dinitro-6-bromophenol,* sulfur-yel prisms(from eth), almost col ndls(from w, alc or benz + gasoline), mp 117-20°, sublimes when heated carefully, explodes when heated rapidly(Refs 3 & 7); *2,6-Dinitro-3-bromophenol,* ndls(from petr eth), mp 131°, vol on steam bath (Refs 4 & 6); and *2,6-Dinitro-4-bromophenol,* lt yel ndls(from w or alc) or orn-red prisms(from eth or AcOH), mp 74-83°, sublimes w/o decompn when heated carefully(Ref 5). All of these isomers form numerous salts which are colored cryst compds, some of which are unstable & expl when heated(eg *Ag salt*). Other props & methods of prepn of these compds are given in:
*Refs:* 1)Beil **6**, [249] 2)Beil **6**, 261 & [249] 3)Beil **6**, 261, (128) & [250] 4)Beil **6**, [250] 6)H.H.Hodgson & F.H.Moore, JCS **1926**, 158,159 7)H.P.Crocker & R.H.Hall, JCS **1955**, 4490 & CA **50**, 10713(1956)

**Trinitrobromophenol,** $(O_2N)_3$Br.$C_6$H.OH; mw 308.64%. Two isomers are described in the literature: *2,4,5-Trinitro-3-bromophenol*(?)(called 2,5,6-Trinitro-3-bromophenol in Ref 3), crysts (from w), mp 146°, vol on steam bath; was prepd by boiling the dipotassium salt of 3,4,6-trinitro-5-bromophenol-sulfonic acid(?) with dil $H_2SO_4$; the *K salt,* $(O_2N)_3$Br.$C_6$(OK).$SO_3K$, yel crysts (from alc) isolated during the above prepn, expl when heated(Refs 1 & 3); and *2,4,6-Trinitro-3-bromophenol,* col lfts(from w), mp 149°, non-vol in steam; was prepd by nitrating 3-bromophenol, 2-nitro-3 or 5-bromophenol, 4-nitro-3-bromophenol, 2,4-dinitro-3 or 5-bromophenol or 2,6-dinitro-3-bromophenol with mixed $HNO_3$-$H_2SO_4$(Refs 2 & 3). Both of the trinitro bromo derivs are expl compds but their expl props were not detd
*Refs:* 1)Beil **6**, [283] 2)Beil **6**, 292 & [283] 3)H.H.Hodgson & F.H.Moore, JCS **1926**, 160-1

**Tetranitrobromophenol,** $(O_2N)_4C_6$Br.OH; mw 353.02, N 15.87%. One isomer is described in the literature: *2,3,4,6-Tetranitro-5-bromophenol or 2,4,5,6-Tetranitro-3-bromophenol,* col crysts(from chlf or $CCl_4$), mp 157°, expl on heating to higher temp; gives a yel color in alc or w soln; was prepd by nitrating 5-nitro-3-bromophenol. Its other halogen analogs are also expl
*Refs:* 1)Beil **6**, 293 2)J.J.Blanksma, Rec **27**, 36(1908) & JCS **92 I**, 126-7(1907)

**Bromophenyltriazene**(called Bromphenyltriazen in Ger), Br.$C_6H_4$.N:N.$NH_2$; mw 200.05, N 21.00%. Three isomers are known: *2-Bromophenyltriazene,* crysts, expl when rubbed; *3-Bromophenyltriazene,* crysts, expl when heated and *4-Bromophenyltriazene,* lfts(from gasoline), mp 36.5°(dec); on standing at RT it transforms into a compd melting at 39° but when recrystd(from eth + petr eth) it again melts at 36.5°; its *Cu salt,* $CuC_6H_8N_3Br$, crysts(from epichlorohydrin), expl in a flame or in contact with concd $HNO_3$. These isomers were prepd by reduction of the appropriate bromoazidobenzene with $SnCl_2$ in HCl + eth. The *Stannic Chloride salt* of each was unstable expl
*Refs:* 1)Beil **16**, (405,406) 2)O.Dimroth & K. Pfister, Ber **43**, 2760-61(1910) & CA **5**, 485-6 (1911)

**Bromopicrin,** See Nitrobromoform under Bromoform and Derivatives

**5-Bromo-3-pyridoyl Azide.** See 5-Bromo-nicotinyl Azide

**Bromoquinone.** See Bromobenzoquinone

## Bromoresorcinol and Derivatives

**Bromoresorcinol;** *Bromoresorcin; Bromo-1,3*

*-dihydroxybenzene or Bromo-1,3-benzenediol* (called Bromresorcin in Ger), $HO.C_6H_3Br$-OH; mw 179.02. Three isomers exist: 2-, 4- & 5-bromo-resorcinol. They are described in Beil
*Ref:* Beil **6**, 821, [819,820]

**Mononitrobromoresorcinol,** $HO.(O_2N)C_6H_2Br.OH$; mw 234.02, N 6.00%. Only two isomers were found in the literature: *5-Nitro-2-bromoresorcinol,* orn-yel ndls(from eth acet + petr eth), mp 201° (dec)(Refs 1 & 2) and *6-Nitro-4-bromo-resorcinol,* crysts(from $CCl_4$), mp 134°(Ref 3). Other props & methods of prepn of these compds are given in the Refs
*Refs:* 1)Beil **6**, [823] 2)G.Heller, Ber **56**, 1875(1923)& CA **18**, 385(1924) 3)N.Kaneniwa, JPharmSocJapan **75**, 785(1955) & CA **50**, 4842 (1956)

**Dinitrobromoresorcinol,** $HO(O_2N)_2C_6HBr.OH$; mw 279.02, N 10.04%. Two isomers are described in the literature: *2,4-Dinitro-6 -bromoresorcinol,* yel crysts(from AcOH), mp 89-90°(Ref 1) and *4,6-Dinitro-2-bromoresorcinol,* yel ndls(from alc), mp 189-93° with partial sublimation(Refs 2,3 & 4). These compds form numerous salts, some of which may be expl. They are, themselves, expl although their expl props were not investigated
*Refs:* 1)Beil **6**, 829 & (405) 2)Beil **6**, 829,(405) & [825] 3)G.P.Rice, JACS **48**, 3130(1926) 4)G.Heller et al, JPraktChem **129**, 211(1931); CA **25**, 2128-9(1931) & BrA **1931A**, 477
*Note:* Higher nitro derivs of bromoresorcinol were not found in Beil or in CA thru 1956

**5-Bromo-1,2,3,4-tetrazole**(called 5-Brom -tetrazol in Ger), $Br.C.NH.N$ (ring: C, NH, N, N, N); mw 148.97, N 37.61%; col crysts(from toluene), mp 147-8° (dec), cryst powd(from w) or ndls(from benz), mp 156°(dec); readily sol in hot alc or eth; mod sol in w with strong acid reaction; sl sol in hot benz; the acidic dissociation constant is $740 \times 10^{-5}$(Ref 3); IR absorption spectra(Ref 4); X-ray diffraction data(Ref 5). It was first prepd by heating cyanogen bromide(BrCN) with hydrazoic acid in eth at 50-60° [Ref 1,p(109)] and later by passing $H_2S$ into a HCl soln of the Cu salt of 5-bromotetrazole which was obtd by treating aq tetrazole-5-diazonium bromide with finely divided CuO in 40% HBr. The diazonium compd was prepd by treating an alkaline soln of 5-aminotetrazole with $NaNO_2$ in a 40% HBr soln (Refs 1 & 2). The *Cupic salt,* grn crysts, detonated when rapidly heated in a melting-point tube or in contact with a flame(Refs 1 & 2)
*Refs:* 1)Beil **26**, (109) & [197] 2)R.Stollé, Ber **62**, 1123(1929) & CA **23**, 4471(1929) 3)E.Lieber et al, JACS **73**, 1793(1951) 4)E.Lieber et al, AnalChem **23**, 1594(1954) 5)L.A.Burkardt & D.W. Moore, AnalChem **24**, 1581(1952).

### Bromotoluene and Derivatives

**Bromotoluene or Bromomethylbenzene**(called Brom-toluol or Brom-methylbenzol in Ger), $Br.C_6H_4.CH_3$; mw 171.05. Three isomers are known: *2-Bromotoluene,* col liq, fr p -27°, bp 180-2°, flash p 175°F, d 1.422 at 25°(Ref 1); *3-Bromotoluene,* col liq, fr p -39.8°, bp 183-4°, d 1.410 at 20°(Ref 2); and *4-Bromotoluene,* wh crysts(from alc), mp 28°, bp 184-5°, flash p 185°F, d 1.400 at 27°(Ref 3). The toxicity of these isomers is not given in Sax(Ref 5) but it is found in Ref 4. Other props & methods of prepn are given in Beil(Refs 1, 2 & 3)
*Refs:* 1)Beil **5**, 304, (153) & [234] 2)Beil **5**, 305, (154) & [235] 3)Beil **5**, 305, (154) & [236] 4)H.Staub in J.Houben, Edit, "Fortschritte der Heilstoffchemie", Pt 2, Vol II, Walter de Gruyter, Berlin(1932), 76 5)Sax(1957), 389-90

**Azidobromotoluene,** $N_3(Br).C_6H_3.CH_3$; mw 212.06, N 19.81%. Two isomers are known: *2-Azido-5-bromotoluene,* flakes, vol in steam; *4-Azido-2 or 3-bromotoluene,* col liq which solidifies on cooling. Other props & methods of prepn are given in Beil
*Ref:* Beil **5**, 333, 334, (163,164) & [255, 256]

**Dinitrobromotoluene,** $(O_2N)_2(Br).C_6H_2.CH_3$; mw 261.05, N 10.72%. Eight isomers are known: *2,3-Dinitro-4-bromotoluene,* col ndls(from alc), mp 129°(Refs 5 & 7); *2,5-Dinitro-4-bromotoluene,* straw-colored ndls(from alc), mp 111°(Ref 5); *4,5-Dinitro-2-bromotoluene,* col lfts(from alc), mp 94-5°(Ref 6); *2,4-Dinitro-5-bromotoluene,* pale yel ndls or prisms(from alc), mp 103-4° or ndls(from alc), mp 114°(Ref 1); *2,6-Dinitro-3 -bromotoluene,* ndls or prisms(from alc), mp 86°, vol in steam(Ref 2); *2,6-Dinitro-4-bromotoluene,* orn-yel ndls(from alc), mp 89-90°(Refs 3 & 7); *3,5-Dinitro-2-bromotoluene,* yel crysts(from alc) or yel prisms(from eth + alc), mp 91-5°, vol in steam(Refs 1 & 8); and *3,5-Dinitro-4-bromotoluene,* yel prisms(from $HNO_3$ or alc), mp 118°, vol in steam(Ref 5). Other props & methods of prepn of these compds are given in the Refs, but their expl props were not reported
*Refs:* 1)Beil **5**, 346, (169) & [265] 2)Beil **5**, (169) & [265] 3)Beil **5**, [265] 4)Beil **5**, 346 &

(170) 5)R.D.Kleene, JACS **71**, 2259(1949) & CA **43**, 6992(1949) 6)J.K.Landquist, JCS **1953**, 2817 & CA **48**, 11427(1954) 7)W.Qvist, ActaAcadAboensisMath et Phys **19**, No 1, 3-12 (1953) & CA **49**, 8992(1955) 8)P.J.C.Fierens et al, BullBelg **64**, 658, 667, 696 & 709(1955) & CA **50**, 11260(1956)

**Trinitrobromotoluene**, $(O_2N)_3(Br).C_6H.CH_3$; mw 306.04, N 13.73%. Only one isomer is described in the literature: *2,4,6-Trinitro-3-bromotoluene*, col ndls(from alc), mp 143-4°, sol in alc, insol in liqroin; was first prepd by nitrating 2,4-dinitro -5-bromotoluene and later by diazotizing 2,6 -dinitro-3-bromo-4-aminotoluene(Ref 1). Qvist et al(Ref 2) prepd this compd by nitrating the 5-bromo deriv of o-cymene(isopropyltoluene) and also by nitrating 2,4-dinitro-5-bromotoluene(Ref 3). The trinitrobromotoluene is definitely an expl compd although no investigator has reported its expl props

*Refs:* 1)Beil **5**, 349 & (174) 2)W.Qvist et al, ActaAcadAboensisMath et Phys **14**, No 1, 3-36 (1942) & CA **38**, 5206(1944) 3)W.Qvist & M. Moilanen, ibid, No3, 9pp(1943) & CA **38**, 5491 (1944)

**Bromotoluidine.** See Bromomethylaniline

**3(or 5)-Bromo-1,2,4-triazole** [called 3(or 5)-Brom -1.2.4-triazol in Ger], HC(=N-NH-N=C.Br) or Br.C(=N-NH-N=CH); mw 147.98, N 28.39%; col prisms(from benz or w), mp 188-9°; readily sol in w; diffc sol in benz or eth; almost insol in chlf or eth acet; was prepd by treating 5-nitrosamino-1,2,4-triazole-3-carboxylic acid with aq HBr(Refs 1 & 2). The expl props of this compd were not investigated

*Refs:* 1)Beil **26**, 21 2)W.Manchot & R.Noll, Ann **343**, 9(1905) & JCS **90** I, 213(1906)

**Bronnert and Schlumberger** patented in England (1896) a method of gelatinizing NC by methanol or ethanol mixed with small quants of org acids (oxalic, citric) or their esters

*Ref:* Daniel(1902), 85

**Bronolithe.** An expl invented by B. de Brones and patented in Germany(1885),consisted of: $KNO_3$ 20-40, double picrate of Ba & Na 15-30, picrate of Pb & Na 8-30, picrate of K & Na 2-10, nitronaphthalene 5-20, sugar 1.5-20, gum 2-3 & lampblack 0.5-4%

*Ref:* Daniel(1902), 85

**Bronstein's Explosives.** Blasting expls which consisted of AN 82.2, sugar 9 & iron pyrites 8.8% (Ref 1); and $NaNO_3$ 30-40, NS 25-55 & marble dust 5-45%(Ref 2)

*Refs:* 1)J.B.Bronstein, USP 986900(1911) & CA **5**, 1995(1911) 2)J.B.Bronstein, USP 988858 (1911) & CA **5**, 2179(1911)

**Brookhaven National Laboratory.** A national research center for fundamental and applied research in nuclear sciences and related subjects. It is an intergral part of the US Atomic Energy Commission's nationwide program. Like other national labs of the AEC, Brookhaven is operated under contract by a private institution, Associated Universities, Inc. The governing body of this nonprofit educational institution is a Board of Trustees made up of one scientist and one administrative officer from each of nine sponsoring universities: Columbia, Cornell, Harvard, John Hopkins, MIT, Princeton, Univ of Pennsylvania, Univ of Rochester & Yale. This huge scientific research estabilishment, which came into being in 1947, is located on 3500acres of scrub oak and pine in the center of Long Island, some 65miles east of New York City

Research at Brookhaven may be summerized under four general headings: *Studies of Atomic Nuclei, Effects of Radiation upon Matter, Radioisotopes and Other Nuclear Tools & Nuclear Technology.* At present the laboratory employs more than 2100 persons, 400 of whom are scientists and 700 are technical personnel.

Each year in the Fall, Brookhaven holds a public visitor's day. Admission is by ticket only; applications should be made to Director's Office, Brookhaven National Laboratory, Upton, Long Island, NY

*Refs:* 1)D.J.Hudges, "The Nuclear Reactor as a Research Instrument", SciAm **189**, No 2, 23-9 (1953) 2)R.A.Beth & C.Lasky, "The Brookhaven Alternating Gradient Synchrotron", Science **128**, No 3336, 1393-1401(1958) 3)D.Puleston, Head, Information Division, "Brookhaven National Laboratory---Present and Future Growth"(June 1961) 4)Numerous booklets & pamphlets available to the public, issued by the Information Division of the Directors Office, Brookhaven National Laboratory

**Brougère Powder.** See Brugère Powder

**Brown Charcoal.** A product made by slightly carbonizing rye straw and used in the manuf of

Brown Powder(qv), described under Black Powder Modifications

**Browning, John Moses**(1855-1926). Amer inventor specializing in automatic small arms. Beginning in 1879 he secured a patent for a breech-loading rifle(sold to the Winchester Co) and until his death he designed many types of rifles, pistols, machine rifles and machine guns. In 1890 a MG of his design, but known as the Colt, was adopted by the US Army. His first automatic pistol was patented in 1898 but it was not manufd in the US due to lack of financial support or interest. He then went to Belgium where the famous FN(Fabrique Nationale) at Herstal-Liège began to manuf his automatic pistol, as well as his later automatic rifles & other weapons (See also Browning's Weapons)
*Refs:* 1)G.M.Chinn, "The Machine Gun", Vol 1, USGivtPtgOff, Washington, DC(1951), 156-86 2)EncyclBritannica, Vol 4(1952), 275 3)W.H.B. Smith, "Pistols & Revolvers", Vol 1 of the NRA Book of Small Arms, Military Service Publg Co, Harrisburg, Pa(1953), 27 & 132 4)W.H.B.Smith, "Small Arms of the World", The Stackpole Co, Harrisburg, Pa(1960), 153-61

**Browning's Weapons.** Many weapons were invented by J.M.Browning, but not all of them were manufd under his name. Some of them were known as Colts, Winchesters, Remingtons, etc. Following is a partial list of Browning weapons manufd during the 20th century:
a)*Pistols, Automatic.* Calibers .32, 9mm and .380; manufd primarily by the FN, Herstal -Liège, Belgium; used beginning 1908 by the US Army(Ref 1,pp 22-6 & 374-7 and Ref 4,pp 216, 228 & 368)
b)*Rifles, Automatic,* Cal .30, Model 1918 and 1918Al, known as **BAR**, adopted during WWI by the US Army; was modified in later models(Ref 1,pp 323-30 & Ref 3, 66; Ref 2, 173-6, 185)
c)*Machine Rifles.* Cal .30, Model 1918A2 and cal 7.65mm, Belgian, MP34(Ref 1, 330 & 377-8; Ref 1a, 23 and Ref 2, 174 & 185)
d)*Machine Guns.* Cal .30, Model 1917 & 1917A and later modifications; cal .50 M2MG and later modifications(Ref 1, 338-45 & 346-54; Ref 1a, 53-58 & 58-65 and Ref 2, 161,164-5,167-72, 177-86 & 327-44)
e)*Browning Aircraft Cannon.* Cal 37mm(Ref 2, 531-6)
*Refs:* 1)W.H.B.Smith, "Small Arms of the World", Military Service Publg Co, Harrisburg, Pa(1948), 22-6,323-30,338-54 & 374-8 1a)Anon, "Small Arms Matériel and Associated Equipment", TM **9-2200**(1949), 23,53-58 & 58-65 2)G.M.Chinn, "The Machine Gun", USGovtPtgOff, Washington, 25, DC, Vol 1(1951), 156-86, 327-44 & 531-6 3)W.H.B.Smith, "Rifles", Vol 2 of NRA Book of Small Arms, Military Service Publg Co, Harrisburg, Pa(1952), 66 4)W.H.B.Smith, "Pistols and Revolvers", Vol 1 of NRA Book of Small Arms, Military Service Publg Co, Harrisburg, Pa(1953), 27,132,216,228 & 368 5)Glossary of Ord(1959), 50 6)W.H.B.Smith, "Small Arms of the World", The Stackpole Co, Harrisburg, Pa(1960), 160

**Brown(or Cocoa) Powder.** See under Black Powder Modifications

**Brown's Dynamite.** A.J.Brown patented in England(1899) a dynamite having the following compn: NG 30, $KNO_3$ 40, $MgSO_4$ 24, collodion cotton 1, turpentine 4 & $Na_2CO_3$ 1%
*Ref:* Daniel(1902), 85-6

**Brown's Powder.** An expl adapted for blasting, and also proposed as a rifle proplnt, consisted of a soln of rosin in linseed oil 8-10, $NaClO_3$ 70-6%, finely divided carbon(preferably lampblack) 4 & wheat flour 14-22 parts. The mixt was pressed and broken into grains
*Ref:* J.M.Brown, USP 1218976(1917) & CA **11**, 1549(1917)

**Broyage**(Fr). Grinding, crushing or pulverizing

**Broyage de Poudre Noire**(Fr). Grinding of BkPdr. The method used in France before WWII is described in Pascal(1930), 201

**Brugère Powder.** A proplnt used with some success in France for the Chassepot rifle. It was prepd by grinding together, pressing and granulating as in the manuf of BkPdr, a mixt of Amm picrate 54 & $KNO_3$ 46%. It was more powerful than BkPdr and gave less smoke
*Refs:* 1)Daniel(1902), 86 2)Marshall **1**(1917), 284 3)Davis(1943), 51 4)Pérez Ara(1945), 223 5)Izzo, Pirotechnia(1950), 212

**Brunswig, H**(1865- ?). Ger scientist specializing in expls. He is the author of the books; "Explosives", Wiley, NY(1912)(English translation by Munroe & Kibler) and "Das Rauchlose Pulver", W. de Gruyter, Berlin(1926) & numerous other publications on expls and re-

lated items

**Brunswig's Test**(Loss in Weight at 110°). A heat or stability test applicable to gelatinized smokeless powder

*Procedure:* An accurately weighed 5-g sample is spread in a thin layer in an open, shallow dish and heated for 72 hrs in a special oven, fitted with a revolving stand. Then the dish is cooled in a desiccator and weighed. The loss in wt is calcd as percentage of original wt. The sample is then reheated for an 8-hr period each day(for 6 to 8 days), reweighed and the loss for each 8-hr period is calcd as % loss(Refs 1, 2 & 4)

Data for losses in wt(for each 8-hr period studied) of well and poorly stabilized powds contg 22.5% NG and 65% NC & other ingredients are given in Ref 1,p 402. During the first 72 hrs all powds showed regular losses averaging 1 to 1.5%. Subsequent losses of poorly stabilized powds increased to 2-2.5% per 8-hr period, while well stabilized powds continued at ca 1% per day. After heating for ca 176 hrs, the poorly stabilized powd losses amounted to 42%, while for well stabilized powds the losses were 18-20% for a 192-hr heating period

Metz(Ref 3) compared Brunswig's Test method with other quantitative stability tests(such as Mayrhofer, Mayrhofer-Will, Hansen and the 85° & 110° Hydrolysis Tests) and with qualitative tests(such as Abel & the 134.5° Heat Tests). Brunswig's method is indicated to be applicable only to extremely stable powders. For example, if a powd is of moderate stability and just passes other quantitative tests, it might not pass Brunswig's Test. On the other hand, if a powd passes Brunswig's Test it usually passes other quantitative tests but may not pass qualitative tests, such as Abel's, Zinc-Iodide-Starch Test & others

*Refs:* 1)Brunswig, Props(1926), 339 & 402 2) Ullmann, Vol 4(1929), 748 3)L.Metz, SS **27**, 150-3 & 188-91(1932) 4)Reilly(1938), 86

**Brynk, A.F.**(1855- ?). A professor at the Russian Artillery Academy, known for his work on ballistics. His course on "Interior Ballistics", published in 1901, was translated into German and in 1902, at the request of the US Navy Dept, was translated by J.B.Bernadou(qv) into English for publication in the USA(1904). In 1898-1901, Prof Brynk & Prof N.F.Drosdov extended Sarrau's formula for the combustion of BkPdr into the domain of smokeless NC proplnts. For the pressure curve, Brynk proposed his own empirical formula

*Ref:* M.E.Serebryakov, "Interior Ballistics", originally published in Moscow(1949) and translated into English by Dr V.A.Nekrassoff (1950), Abridged Edition, pp 3,27 & 32(Contract NOrd 10260)

**BSI Sieves**(British Standard Institution Sieves). A series of fine mesh, std test sieves of specification governed by British Standards Spec No 410-1943, available from BSI, Victoria St, London SWI. These sieves with their mesh numbers & openings are compared with US, Tyler & German std sieves in Vol 1, Table I, p 674 of this Encyclopedia

**BSP Powder**(Poudre B, Siège et Place). A powd previously used in France for siege howitzers

*Ref:* Marshall 1(1917), 297

**BSQ.** A modified double-base propellant developed at ABL. Its compn & props are given in conf "Propellant Manual", SPIA/M2(1959), Unit No 519

**"B-Stoff".** According to RocketEncycl(1959), 59, this is a code name for hydrazine hydrate, $H_2N.NH_2.H_2O$, one of the Ger rocket fuels used during WWII. The same code name used during WWI for Ger lachrymator *Bromoacetone*(qv)

**BSX.** A code designation for the expl 1,7 -Diacetoxy-2,4,6-tetramethylene-2,4,6-trinitramine (qv)

**BTM.** A castable HE compn contg Tetryl 55, TNT 25 & Al 20%. Its cast d is 1.77 and relative fragementation efficiency 140% TNT

*Ref:* S.Fleischnick, PATR **1595**(1946),p 2 & 'table 1

**BTNEN.** Abbr for Bis(2,2,2-trinitroethyl)-nitramine, which is designated as *HOX*. Same as Di(trinitro-ethyl)-nitramine, listed under Diethylamine and Derivatives

**BTZ.** A series of French army missiles developed by the Bureau Technique Zbrowski in Brunoy, Seine et Oise, France. Among them are BTZ 412-01(Ogre I), BTZ 411-01(Lutin), and BTZ 420-01(Naine Bébé)

*Ref:* G.Merrill, "Dictionary of Guided Missiles and Space Flight", Van Nostrand, NY(1959), 103

**Bubbles of Gas in Explosives.** The presence of minute gas bubbles(such as air bubbles) which are trapped in liquid, plastic, gelatinous or solid expls, greatly increases their sensitivity to detonation by impact. This increase in sensitivity is attributed to adiabatic compression and heating of the entrapped bubbles. This phenomenon was investigated in England by Bowden et al
*Refs:* 1)F.P.Bowden et al, Nature **157**, 105(1946) & CA **40**, 2306-7(1946) 2)F.P.Bowden et al, PrRoySoc **A188**, 291-311(1947) & CA **41**, 3627 (1947) 3)F.P.Bowden & A.D.Yoffe, "Initiation and Growth of Explosion in Liquids and Solids", Cambridge UnivPress, Cambridge, England(1952), 29-63

**Bubbles of Gas in Liquid Explosives. Suppression of Bubble Initiation.** It has been shown(see previous item) that one of reasons for the increase in sensitivity of expls to initiation by impact is due to the adiabatic heating during sudden compression of small trapped gas bubbles. Gray & Yoffe(Ref 1) stated that initiation occurs as a result of the burning of explosive vapor in the gas phase prior to decompn of the liquid, such as NG

In order to reduce the fire and expln hazard in pressing, rolling and extruding certain thermoplastic expls contg liq expls(such as NG) due to the adiabatic compression of entrapped gases, it has been proposed by Jones(Ref 2) to incorporate in formulations some volatile substances to serve as inhibitors. Jones stated that ideal expln inhibitors are complex org vapors which dissociate endothermally below the ignition temp of the expl compn and thus absorb heat and reduce the expln potential. The quantity of inhibitors added to NG(or other liq expls) will be detd by their heat-absorbing power and vapor pressure. The names of these inhibitors are not revealed in Ref 2
*Refs:* 1)P.Gray & A.D.Yoffe, Research(London) **2**, 339-40(1949) & CA **43**, 8139(1949) 2)E.Jones, Nature **173**, 77-8(1954) & CA **48**, 5499-5501(1954)

**Bubble Period Measurements**(Used for Bubble Energy Measurements). See under Underwater Explosions

**Buck's Explosive.** An expl compn obtained by blending two mixts previously prepd in separate kettles. Mixt 1 was prepd by fusing together 50 parts PA & 50p DNPh to which was later added 4p collodion cotton. Mixt 2 was obtained by blending at 130° 50p Ba nitrate with 4-5p paraffin. The final blend consisted of 10 lb of mixt 1, 10 lb mixt 2 and 5/16 lb powdered charcoal; it was claimed that charcoal exerted a most favorable influence on the action of the expl
*Refs:* 1)C.U.Buck, USP 940580(1909) & CA **4**, 514(1910) 2)Colver(1918), 324

**Budenberg's Explosive.** A blasting powder: Na nitrate 40, K nitrate 38, sulfur 12 & charcoal 10%
*Ref:* Pepin Lehalleur(1935), 287

**Buechert,** of San Francisco, Calif, patented in 1894 an expl compn consisting of $NH_4ClO_3$, $(NH_4)_2SO_4$, $NaNO_3$, NG & woodpulp. In order to prevent the reaction in storage betw $(NH_4)_2SO_4$ & $NaNO_3$, the crysts of these compds were precoated with Al oleate
*Ref:* Daniel(1902), 87

**Bühle, Emil Georg**(1890-1956). Swiss engineer specializing in ammunition and weapons. Formerly Director of the internationally known "Werkzeugmaschinenfabrik Oerlikon Buhrle & Co", Switzerland
*Refs:* 1)Anon, Explosivst **1957**, 11(a brief obituary) 2)"Oerlikon Pocket Book", Zürich -Oerlikon(1958), 13

**Buildings and Other Structures at Ordnance Establishments.** Any plant, works, arsenal, depot, proving ground and other activity formerly under control of the US Chief of Ordnance may be considered as an Ordnance Establishment

The area occupied by such an establishment generally includes the following buildings and other constructions:
A)*Administration Buildings* or any other administrative offices which function for the establishment as a whole in contrast to *field offices*(qv)(Ref 1, secn 8 and Ref 2, secn 2,p 1)
B)*Operating Buildings*(except magazines) in which operations pertaining to manufg, processing or handling expls, ammo or ammo components are performed. A group of bldgs used to perform the consecutive steps in the manuf of processing of expls or ammo is called an *operating line.* For example, in the manuf of TNT, the buildings, known as mono-, bi-, and tri-(nitration) houses, which are followed by purification, flaking and packing houses, consitiute a "line"("TNT line") (Ref 1, secn 8 and Ref 2, secn 2,p 10)
C)*Auxiliary Buildings* supplement operating buildings, lines or areas, but which are not directly utilized for the production activity

Following are examples of such bldgs:
a)Field Office is a bldg housing offices of administration personnel responsible for a part of the establishment, such as one of the operating lines
b)Buildings for storing acids, inert components and materials(such as toluene, hexamthylene-tetramine, cellulose, etc) used in the manuf of expls. The area in which these bldgs are situated may be called *inert area*
c) Service Magazines used for intermediate storage of expls or ammo, not exceeding the minimum amt necessary for manufg operations
d)Packing and Shipping Houses
e)Power House and Electrical Substations
f)Pump, Valve, Compressor or Fan houses; Fire House
g)Laboratory, such as Chemical, Physical or Ballistic
h)Surveillance Buildings for Explosives or Ammunition
i)Change House with facilities for employees to change clothing, bathe, etc
j)Guard House, Bombproof Building and other Personnel Shelters
(Ref 1, secn 8 and Ref 2, secn 2,p 2)
D)*Magazine Buildings* specifically designated for the storage of expls, ammo or loaded components

Following types of magazines may be found in Ordnance establishments:
a)Igloo(barrel or arch) type
b)Box(earth-covered, reinforced concrete) type
c)Stradley(Yurt)(earth-covered, reinforced concrete)type with vertical sidewalls and arched roof
d)Corbetta(earth-covered, beehiv e or dome) type
e)Aboveground types, include the magazines originally named: Ammunition Magazine, Black Powder Magazine, Primer & Fuze Magazine and Smokeless Powder Magazine
f)Richmond type(two sides and rear are barricaded) also belongs to aboveground types
g)Hillside type
h)Subsurface type(all portions underground)
(See Ref 2, secn 2,pp 7-9 & secn 18, also Ref 3,pp 22-35 & 36-50)
E)*Inhabited Buildings* occupied in whole or in part as a habitation for human beings or where people are accustomed to assemble
*F)Barricades, Natural and Builtup; Installation Boundaries, etc.* See Barricades in this vol as well as in Ref 2, secn 17, pp 24 & 32 and in Ref 3,pp 35 & 108
G)*Utilities*, such as water, air, steam, electricity and sewage, necessary for the operation of an establishment(Ref 2, secn 2,p 16)
H)*Dunnage Yard* is an open air space for storing the reserve supply of lumber for an establishment (Ref 3,p 140)
I)*Holding Yard* is a group of RR tracks used to store cars of expls, ammo or inert materials for indefinite periods. The yard may also include areas for storing or parking trailers contg expls and ammo(Ref 2, secn 2,p 6 & Ref 3,pp 54 & 141)
J)*Classification Yard* is a group of RR tracks used for receiving, shipping and switching cars contg expls, ammo or inert materials(Ref 2, secn 2,p 3 & secn 17,p 14 and Ref 3,p 53)
K)*Loading Docks* are facilities at ground level or elevated structures designed and installed for transferring expls, ammo and inert materials between automotive vehicles and RR cars(Ref 2, secn 2,p 7 & secn 17,p 16 and Ref 3,pp 54-5)
L)*Gasoline and Other Liquid Fuel Tanks* should be located at distances ranging from 100 to 1800 ft depending on the bldg classification because they are fire hazards(Ref 2, secn 17, p 18 & secn 24,p and Ref 3,pp 55-6)
M)*Restricted Area.* Some Ordnance establishments may contain a fenced area where the entrance and egress of personnel and vehicular traffic are controlled for reasons of safety and security(Ref 2, secn 2,p 12)

All the above-mentioned bldgs and other structures within US Ordnance establishments shall be located at such distances, one from the other, as prescribed by Quantity-Distance Tables given in Ref 2, secn 17 and Ref 3,pp 44-80

The quantity of expl material and distance separation relationship which provide defined types of protection are based on levels of risk considered acceptable for the stipulated exposures
*Refs:* 1)US Chief of Ordnance, "Safety and Storgage Manual for Explosives and Ammunition", PP Form No 5994, Washington, DC(1928), secn 8
2)US Ordnance Corps Manual Ord M 7-224, "Ordnance Safety Manual", Washington, DC(1951)
3)US Dept of the Army Technical Manual "Care, Handling, Preservation, and Destruction of Ammunition", TM 9-1903, Washington, DC(1956)
4)B.Kanouse & C.V.Ruskewicz, PicArsn, Dover, NJ; private communication(1961)

**Built-up Detonation.** See under Detonation

**Built-up Guns.** One of such weapons was the Brit breech-loading gun invented ca the beginning of the 16th century. Its barrel was fashioned by

welding together bars of iron to form an open cylinder. The powder chamber was separated from the barrel, and before firing, was screwed into it by means of an uninterrupted thread. Some of these guns were used in 1588 by the Brit Navy against the Spanish Invincible Armada(Ref 3). The so-called "leather" gun, invented by Wurmbrandt of Sweden and used by the Army of Gustavus Adolphus(beginning of the 17th century), consisted of a copper tube bound with iron rings and ropes and covered with leather. In some later built-up guns, wire was neatly wound around the barrel at high tension(Ref 1,p 61 & Ref 2,p 83)

A modern built-up gun consists of two or more concentric cylinders assembled by shrinkage. In a two-piece gun the outer cylinder, the jacket, is heated and slipped over the inner cylinder, the tube. As the jacket cools, it fits snugly over the tube. This process compresses the inner tube and the elastic strength of the gun is considerably increased. Another advantage of built-up gun is the removability of the inner tube, or liner, when its rifling wears out(Ref 2,p 84).The 240mm Howitzer, briefly described in Ref 1,p 156, may be cited as example of such guns

*Refs:* 1)Hayes(1938), 61-4 2)J.R.Newman, "The Tools of War", Doubleday, Doran & Co, NY(1943), 83-4 & 156 3)J.F.C.Fuller, "A Military History of the Wasetern World", Funk & Wagnalls, NY, Vol 2 (1955), 11

**Bulgarian Armament.** No information at our disposal

**Bulk and Condensed Powders**(Sporting Smokeless Propellants). Sporting smokeless proplnts have now nearly completely replaced black powders because they have the following advantages over BkPdrs: smokelessness, smaller recoil and less noise. Sporting smokeless proplnts may be divided into bulk and condensed types. Bulk pdrs are faster burning than condensed pdrs and have a lower density

The original bulk pdrs were prepd so that the chge for a 12-gage shotgun would occupy the same space in the paper cartridge(of 2.5" normal length) as the standard chge of 82 grains of BkPdr occupying a space of 3 liq drams(10.65 ml). The first pdr of this kind, that of a German Officer Schultze(1864), was prepd by nitrating wood fibers and then impregnating them with a soln of $KNO_3$ alone or with $Ba(NO_3)_2$. A better pdr was obtained in Austria(early 1870's) by partially gelatinizing nitrated wood with ether-alcohol. This improved pdr was known as *Collodin.* The next improved bulk pdr was *EC Powder,* patented in 1882 by the Explosives Co of Stowmarket, England. It consisted of nitrated cotton(12.5 -12.8% N) mixed with K & Ba nitrates and a small amt of dye. It was made into grains which were then partially gelatinized with eth-alc. Some later pdrs contained Ba nitrate but no K nitrate. Ba nitrate has the advantage of being non-hygroscopic and practically smokeless, but it has the drawback of leaving a residue,in the gun barrel,which is difficult to remove. A small propn of vaselin or paraffin wax was sometimes added to moderate the rate of burning. Starch was used occasionally as a binder and camphor to improve gelatinization. Some pdrs contained nitrated benzene or toluene which served as moderators of burning and as auxiliary gelatinizers. Lampblack, woodmeal, various gums & K ferrocyanide were also used as ingredients, and a small quantity of powdered chalk was added for stabilization. Some pdrs were graphited(Refs 1,2,3,4 & 5)

According to Thorpe(Ref 4,p 528), in the prepn of bulk pdrs the mixts of NC with other ingredients are granulated prior to their treatment (mostly on the surface) with a solvent. In order to granulate the mixts, they are sprinkled with water and then either placed in a rotating drum or spread out on a rapidly oscillating table. Another method is to slightly compress the moist mixt and then to break it up into grains which are screened and dried. The original standard Brit chge for sporting cartridges was 42 grains, but later the 33-grain chge became more common. There are also 38-, 36- and 30-grain charges(Ref 4,p 528). The gelatinization of NC in the 30-grain pdrs is nearly complete which makes them similar in nature to condensed pdrs(see below)(Ref 2,p 83). *Amberit, EC, Henrite, Imperial Schultze, Kynoch's Smokeless, Ruby* and *Smokeless Diamond* are examples of European bulk pdrs

Davis(Ref 5,pp 289-92) describes the method of preparing US bulk pdrs having the following compns:NC(12.9-13.15% N) 84-89, K nitrate 6.0-7.5, Ba nitrate 2.0-7.5, starch 0-1.0, paraffin oil 0-4.0 & DPhA 1.0%. The microscopic appearance of a bulk pdr manufd by Western Cartridge Co(now Olin-Mathieson Chemical Co) is given in Ref 5,p 288

The *condensed* pdrs have higher density than bulk pdrs and the charge occupies only 1/3 to 1/2 the volume of a BkPdr chge. These pdrs consist of completely gelatinized NC with

practically the same additives as used in bulk pdrs. They are manufd by methods similar to those used for flake rifle proplnts. Briefly described, the gelatinized pdr mixt(paste) is rolled into thin sheets which are cut into small flakes and dried. The requisite rate of burning is obtained by adjusting the size and shape of the grains(Refs 1,2,3 & 4)

One of the great disadvantages of condensed pdrs is that, due to their small bulk, they require special cartridge cases with a cone of pasteboard to fill up part of the base. Otherwise the case would not be entirely filled. Because of the small space occupied by the pdr chge, very slight variations in the strength of the cap and other conditions could produce great variations in the pressure generated. The gun might therefore be strained dangerously and difficulties are sometimes experienced in extracting the cartridge cases. In loading cartridges, the pdr is always measured by volume; the higher the d of the pdr, the greater is the error in wt due to slight differences in vol. For these reasons bulk pdrs are usually preferred to condensed pdrs. *Cannonite, Shotgun Rifleite* and *Sporting Ballistite* are examples of European condensed pdrs. *Indurite* of Munroe is an example of an Amer condensed pdr(Refs 1,2 & 4)

Ger sporting pdrs are listed by Brunswig (Ref 3,p 134)

According to Thorpe(Ref 4), some sporting pdrs are made as follows: the grains are thoroughly gelatinized and, while they are still wet with solvent, treated with steam. This causes rapid evaporation of solvent, leaving the grains in a state which is intermediate between that in bulk and condensed pdrs

*Refs:* 1)Marshall 1(1917), 322-35 2)Barnett(1919), 82-7 3)Brunswig(1926), 134-5 4)Thorpe 4(1940), 528 5)Davis(1943), 287-92

**Bulk Compressibility.** See Bulk Modulus and Bulk Compressibility

**Bulk Density.** See under Density

**Bulk Modulus and Bulk Compressibility.** According to Cramer(Ref 5,p 1), one of the important constants of an isotropic elastic solid is the bulk modulus (K) or its reciprocal the bulk compressibility(B). The K is defined as the ratio of stress to strain when the stress is a pressure applied equally on all surfaces of the sample and the strain is the resulting change in volume per unit volume. If a sinusoidally varying pressure is superimposed upon any static pressure that may be present, a sinusoidally varying strain of the same frequency will occur. The ratio of these sinusoidal amplitudes is called the *dynamic bulk modulus*. The quantity will vary to some extent with frequency due to the finite time required to reach thermal and structural equilibria. When dissipation of energy occurs during deformation of the material, the strain will lag behind the stress by an angle $\delta$

The apparatus used by Cramer(Ref 5) for dynamic modulus measurements was that devised at the US Naval Ordnance Laboratory by Sandler (Ref 2). This apparatus is actually a modification of one described by Meyer & Tamm(Ref 1). The instrument used by Cramer is shown schematically in Fig 1,p 2 or Ref 5

From data obtained with this apparatus, the value of K may be calcd from the following equation: $K=\frac{\rho C^2 f_o V'}{V\delta f(1+\eta^2)}$, where $\rho$ is the density of water(g/cm$^3$); C the velocity of sound in water in the tube of the apparatus(cm/sec); $f_o$ the resonance frequency of the water column with no sample present(cps); $V'$ the volume of the sample(cm$^3$); V the vol of water in the tube(cm$^3$), $\delta f$ the frequency shift in the resonant frequency after insertion of the sample(cps) and $\eta$ the quantity known as the "loss factor" or "loss tangent", ie, $\eta=\tan\delta$. As the value of $\eta$ is very small(less than 0.1) for rigid materials, such as cast or highly compressed HE's no attempt was made to determine its value and $\eta$ was assumed to equal zero

The following table gives the bulk modulus data(K) for several HE's and wax at temps of 25-30° as detd by Cramer(Ref 5,p7):

Table

| Material | Density | Bulk Modulus x $10^{-10}$ dynes/cm$^2$ |
|---|---|---|
| Comp B-60/40 (with RDX 75 micron size) | 1.72 | 4.14 |
| Cyclotol-75/25 | 1.74 | 3.09 |
| TNT | 1.56 | 2.92 |
| Comp B(RDX 62.5 TNT 35.6 & wax 1.9%) | - | 3.56 |
| Comp B(RDX 61.9, TNT 35.6 & wax 2.7%) | 1.68 | 2.34 |
| PETN | - | 4.60 |
| Wax | 0.91 | 2.96 |

The bulk compressibility(B) is calculated from the equation B=1/K

For description of an apparatus used by Philipoff & Brodnyan, see Ref 3,and of that used by McKinney et al, see Ref 4

*Refs:* 1)E.Meyer & K.Tamm, AkustZeitschr **7**, 45-50(March 1942), "An Accustic Method for Determining the Dynamic Compressibility and Loss Factor of Elastic Substances" 2)C.S. Sandler, NAVORD Rept 1524(Sept 1950), "An Accoustic Technique for Measuring the Effective Dynamic Bulk Modulus of Elasticity and Associated Loss Factor in Rubber and Plastics" 3)W.Philipoff & J.Brodnyan, JApplPhys **26**, 846-9(1955), "Preliminary Results in Measuring Dynamic Compressibilities" 4)J.E.McKinney et al, JApplPhys **27**, 425-30(1956), "Apparatus for the Direct Determination of the Dynamic Bulk Modulus" 5)W.S.Cramer, NAVORD Rept **4380**(Sept 1956), "Bulk Compressibility Data on Several Explosives" 6)J.Alster, PicArsn, Dover, NJ; private communication(1961)

**Bulk(or Volume) Strength of Explosives.** Same as Cartridge Strength. See under Strength of Explosives

**Bulldog Brand Powder.** A safety mining expl: $KNO_3$ 83.5-86.3, sulfur 13-14 & charcoal 1-2.5%, patented in England by Curtis et al in 1899. A fairly large propn of S and a small propn of C were proposed in order to lower the temp of combustion and to prevent formation of CO and $K_2S$

*Ref:* Daniel(1902), 87-8

**Bulldog Missile.** A US Navy air-to-surface missile powered by a solid propInt. The missile was developed by the Glenn L. Martin Co as a successor to the Bullpup Missile(qv). It has a greater range than the Bullpup and can carry a nuclear warhead if required

*Refs:* 1)G.Merrill, "Dictionary of Guided Missiles and Space Flight", Van Nostrand, NY(1959), 104 2)Glossary Of Ord(1959), 50 3)C.E.Davis, "The Book of Missiles", Dodd, Mead & Co, NY(1959), 30

**Bulldog, Special.** A Brit permitted expl patented ca 1901: $KNO_3$ 84-6, charcoal 12-13, basic Mg carbonate 2.5-3.5 & moisture(max) 2%. It was used in compressed form at a density not higher than 1.45

*Ref:* Daniel(1902), 88-9

**Bullet Fit(or Jump) Test.** See under BULLETS TESTS

**Bullet Impact Test**(Rifle Bullet Test). See under BULLET TESTS

**Bullet Penetration Test.** See under BULLET TESTS

**Bullet Pull Test.** See under BULLET TESTS

## BULLETS

A bullet or "small ball"(from the French "boulette") is a projectile(missile) which is discharged from a small firearm, such as a pistol, revolver, shotgun, rifle, machine gun, etc

*Historical*(Refs 1,4,5,9,10 & 12). The first infantry firearm was invented ca 1350, about 100 years later than the cannon. This primitive small arm was called "baston-à-feu" in Fr and *hand-gun* in Eng. It was a simple iron tube attached to a long, straight wooden stock. The butt end of the tube was closed and provided with a "touchhole", bored from the exterior. The charge, consisting of BkPdr, a wad and one or several bullets, was introduced through the muzzle and fired by thrusting a heated wire through the touchhole. The wire was soon(ca 1405) supplanted by a "time match" or simply a "match" which was a string of cotton or hemp boiled in saltpeter or the lees of wine. The primitive bullets were either stones or metallic slugs(shots) of irregular sizes and shapes. The same kind of slugs were used in the first cavalry firearm, which was a half-sized handgun attached at its butt end to a long stock. During firing the gun rested on a forked stand poised on the saddle, while the end of the stock was held against the chest. Its name, *poitrinale* was derived from the Fr "poitrin", which meand chest. This weapon, also called *petronel,* was the predecessor of pistol and carbine(Ref 12b,p 125). The *arquebus*(see Vol 1,p A488-L) improved the handgun by having a bent stock easily fitting the shoulder of a man, instead of a straight stock; the butt end of the improved stock was held under the armpit. At first, the same kind of slugs as were used in the handgun were used in this weapon, but these were later replaced by small cast spherical lead slugs(balls). As early lead balls were smaller than the bores of arquebuses(which were of different calibers), considerable portions of the powder gases

escaped through the muzzle thus lowering the pressure behind the ball. This caused short -range and inaccurate firing in all early firearms

When the caliber of the arquebus was standardized as in "arquebus of caliber", better known as *caliver*(bore diam ca 3/4"), the balls were cast of nearly the same diam as the bore of caliver. Standardization of the caliber improved the performance of arquebus and of the cavalry firearm, which was the "half-size arquebus", known as *demi-hague* and later *pistol*. This was at first 25" long and then was reduced to ca 12" in length. Rifled pistol was invented at the end of 16th century

The improvement in performance of arquebus was also due to the replacement of the "time match" method of ignition by a firing mechanism known as the *matchlock*(ca 1450) and later by the *wheellock*(ca 1520). The wheellock was a device particularly suitable for pistols but rather weak for larger firearms. The short pistols of the 17th century, known as *daggs*, were also equipped with wheellocks

When a larger infantry firearm, the *musket*, was introduced during 1520-1540 by the Spanish, it became possible to fire bullets as heavy as 2.5lbs and which could stop a horse at 500 yds. This was a formidable weapon which contributed much to successes of the Spanish Army in conquering the Netherlands

In early firearms there was no cartridge to hold the chge of BkPdr or the balls. The first cartridge, invented ca 1560, was a paper bag for holding BkPdr only, but a later invention(ca 1590) intended to have BkPdr and balls as one unit. The latter cartridge was used in the Army of Gustavus Adolphus, King of Sweden(1611-1632). The cartridge consisted of a roll of paper which enclosed a BkPdr chge and one or several balls. The ends were either sealed or tied with a piece of string. The cartridge was then greased to waterproof it and to lubricate the bore. The use of ready-made paper cartridges permitted more rapid loading and firing than when the loose BkPdr chge and the bullet were loaded separately. Other improvements in muskets included the replacement of matchlock and wheel-lock by flintlock(toward the end of the 17th century) and later by the introduction of a *percussion cap*(at the beginning of the 19th century). There was no improvement, however, in bullets; they were still spherical in shape, although much smaller(1/2 oz) than used in Spanish muskets(2.5lbs) because of the gradual reduction in size of muskets

Although rifled firearms were invented in the 1st quarter of the 16th century, practically no nation used them because with round bullets they offered very little advantage over the smooth-bore arms unless the balls were rather tightly fitting. The rifled firearms became of great advantage later when elongated bullets were used, but these were not invented until the 1st quarter of the 19th century

It may be of interest to know that some soldiers in the North American Continental Army were equipped during the Revolutionary War (1775-1783) with a sort of rifled firearm of unknown European origin. These rifles were very effective when using *patched bullets*, which were nothing but balls of diam slightly smaller than that of the rifle bore, wrapped in a small patch of greased buckskin, linen or other suitable material. The patch enlarged the diam of the ball to make a tight fit in the barrel. When a patched bullet was pushed down to its seat above the powder, the patch carried with it the residue remaining from the previous firing, thus automatically cleaning the bore with eack loading. When the bullet was discharged, the patch, fitting tightly into the grooves of the rifling, imparted the necessary rotation to the ball and then fell off soon after it left the muzzle. Despite the unusual success of the patched ball, the European nations continued to use naked balls, even in rifled firearms, which came into use toward the end of the 18th and beginning of the 19th century. The British created in 1800 a branch of the Army called the Rifle Corps. At first the Corps was equipped with the Baker rifle(cal ca .615) and then with the Brunswick rifle. These rifles used naked round balls and for this reason were not as effective as Amer rifles using tightly-fitting patched balls

The problem of producing a suitable military rifle missile without resorting to the patch was solved in 1823 when a special elongated bullet was invented by the Brit Capt Norton. The base of Norton's bullet was hollowed out in such a manner as to be expanded by the pressure developed by the powd gases behind it at the instant of firing. This action sealed the bore against the escape of gas and also forced the expanded portion of the bullet into the rifling grooves sufficiently to attain the necessary rotation for accurate flight. This design was followed in 1836 by another elongated bullet invented by Greener, a famous Brit

gunmaker of the period. His bullet was provided with a base cavity into which a conical plug was fitted. When the charge was fired the plug was driven forward far enough into cavity to expand the walls of the bullet into the rifle grooves which surrounded it. A different type of expandable bullet(cylindro-ogival in shape) was designed in 1828 by the French Capt Delvigne, and also by Col Thuvenin. The combination of the improved bullet of Delvigne with that of Thuvenin was adopted in 1846 by the French Army. The next improvement in elongated bullets was the famous *Minnie Ball* designed by the French Capt Minnié. This bullet, cylindro-ogival in shape, combined the best features of the inventions of Norton, Greener and Delvigne. It used an iron cup in the hollow base which expanded to fit the rifling when the gun was fired

According to Johnson & Haven(Ref 4,pp 26-9), by 1850 quite a number of elongated bullets were known. They were, however, short in comparison with current bullets. The most efficient of older, elongated bullets was claimed to be the Minnie Ball. This bullet was used during the Amer Civil War(1861-65). Schematic views of 60 varieties of elongated bullets used in the middle of the 19th century are given on pp 26-8 of Ref 12

About 10 years before the Amer Civil War, there appeared in Europe the so-called *explosive bullets* or *shell bullets*. Early expl bullets, used for big game hunting, contained in a well drilled into their bodies, a chge of BkPdr which was ignited by a percussion cap placed in the nose of the bullet. Forsyth modified the bullets by making them in two pieces which were swaged together after loading. (This would seem to be a dangerous operation with the primer present). Another variant was the bullet of Col Jacob of Bombay Artillery. It was a cylindro-ogival, flat-nose, caliber .532(12 gage), 2 1/2-calibers -long bullet, cast with 4 broad, long lugs on its cylindrical surface, which fitted into as many grooves in the bore. A cavity in the nose carried a chge of expl which detonated on impact. The bullet was intended to be fired from a double-barreled military 12-gage rifle. The range was up to 2000 yds and it was claimed that such a bullet could explode an ammo dump at a distance of 1800 yds. According to Lewis(Ref 12), an Amer modification of this bullet(by Mead) was used during the Amer Civil War. Among other numerous inventions of expl bullets may be mentioned that of S.Gardiner, patented in 1863 and called "musket shell'. This expl bullet, as well as some other bullets which were used during the Amer Civil War, are briefly described in Ref 12

According to Marshall(Ref 2a,p 176), machine guns, used in air war, fired a proportion of explosive bullets with the object of igniting hydrogen in the balloons of airships and gasoline in the tanks of airplanes. The expl bullets used by the Germans had a percussion cap in the nose which was detonated by the shock of the discharge and ignited a pellet of delay compn, which in turn fired an expl chge consisting of $KClO_3$, $Sb_2S_3$ & S

Among the numerous variants of elongated bullets patented in the 2nd half of the 19th century, may be mentioned the one proposed in 1857 by Sir Joseph Whitworth. It was a cylindrical bullet, the rearward portion of which was hexagonal. The gun had a cal .45 barrel, hexagonal in section and with the hexagon of the bore twisted upon itself in order to give the bullet the rotation normally imparted by other methods of rifling

It might also be mentioned that ca 1850 there was patented in the US a "self-propelled" bullet intended to be fired from the so-called "Volcanic" rifle or pistol. Its cylindrical body had a hollow base which housed a small amt of MF. When struck with the firing pin, the MF detonated and pushed the bullet toward the target. These bullets were not very successful

Up to the middle of the 19th century, there were no metallic cartridges to house a BkPdr chge and a bullet. The first workable metallic cartridge was invented in 1846 by Houiller, a Fr gunsmith. The device invented by him is now known as *pin-fire* cartridge(see under Cartridges). The same inventor also patented the *rim-fire* cartridge. The *center-fire* cartridge was invented in 1858 by Morse(US) but it did not gain wide acceptance until the rather complex design was simplified by Potet(France), Dan Baxter(England) and most notably by Berdan(US)

With the invention of metallic cartridges, it became possible to use *breech-loading* rifles (see under Breech-loading Weapon in this Volume)

With the development, in early 1880's, of NC smokeless proplnts suitable for military purposes, it became evident that, due to the rather high temp of burning of such proplnts, it was necessary to protect the naked bullets from the

hot gases in order to prevent melting of the lead. This was achieved by the invention, in the early 1880's, by Major Rubin of the Swiss Army of *jacketed* bullets(a lead core cast in a case of harder metal). As the ballistic potential of smokeless proplnts is much higher than that of BkPdr, weapons(and consequently bullets) of smaller caliber, such as 6-8mm, became predominant

Further improvements in bullets were made betw 1900 and WWI. They consisted in sharpening the nose(pointed-nose bullets), bevelling the base(boat-tailing, tapering) and replacement of steel and cupro-nickel in the jacket by *gilding metal* and allied alloys in order to eliminate excessive bore erosion and metal-fouling

An interesting bullet and its rifle were designed in Germany before WWII by Halger. The rifle was provided with a barrel having a bore part cone and part cylinder. The bullet was *flanged* with flanges which folded back against the body when the missile entered the constricted (cylindrical) portion of the barrel(Ref 10,p 813)

*Bullets, Description:* The following types of bullets are used in modern small arms:

**A)Bullets, Lead.** Balls made from pure lead are called "soft" or drop balls, but usually lead is combined with tin and/or antimony(for hardness). Such balls are called "chilled" shots. This alloying reduces the tendency of the lead to adhere to the barrel in patches. It also helps to prevent the bullet from "stripping", that is from jumping the rifling of the weapon. The current lead bullets may be subdivided into spherical (ball, shot or pellet) and cylindrical types

*a)Ball or Pellet Lead Bullets,* used in shotgun shells and caliber .45 shot cartridges, range in size betw 0.08" and 0.34". Shotgun shells are identified as to the size of the "gage" and not by caliber. The gage of a shotgun refers to the number of pure lead balls of the diameter of the bore required to weigh 1lb. For example, the shotgun with a bore of 0.729" is a 12-gage weapon because 12 lead balls of that diam would weigh 1lb(Ref 8,pp 65-6 & 68-70)

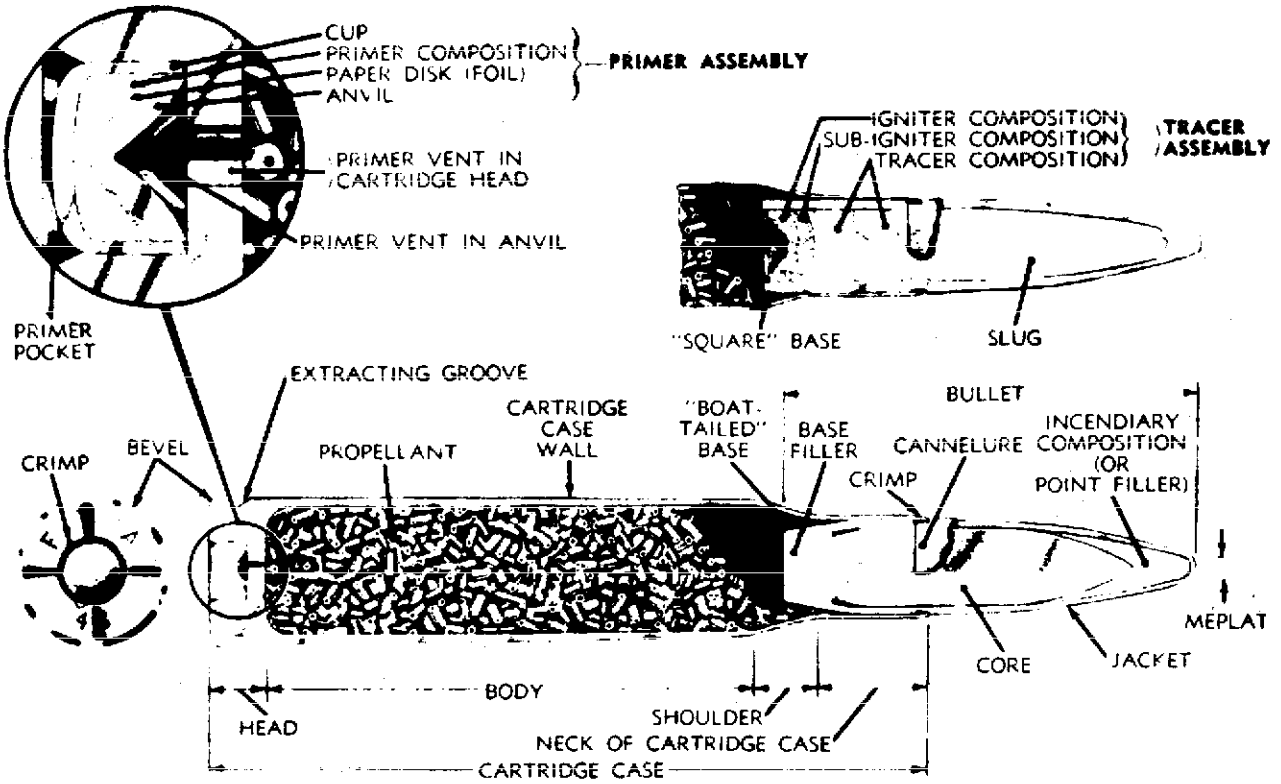
*b)Bullets, Cylindrical, Lead.* Lead alloy bullets, cylindrical in shape with a rounded nose and flat base, are currently used in cal .22 rifle ammo and in many revolver cartridges. In order to reduce "leading" of the barrel, the bullets are generally lubricated with a grease or other lubricating substance which is placed in two or more cannelures or grooves cut around the bullet. The "outside-lubricated" bullets, such as cal .22 rifle and cal .38 short Colt revolver, have cannelures and lubricant on the outside when the bullet is assembled in the cartridge case. The cannelures and lubricant of "inside-lubricated" bullets are beneath the neck of the cartridge case and, therefore, are not visible in the assembled cartridge. The diameter of a lead alloy bullet is generally 0.003" greater than the bore diameter between grooves(see Note below)(Ref 8,p 66)

*Note:* The *caliber* of a weapon is the diam of the *bore*(measured betw opposite *lands*) expressed in inches(US or Brit weapons) or in millimeters (other countries' weapons). The *lands* of the rifling of a weapon are the raised spiral portions formed by cutting spiral *grooves*(generally 0.003 or 0.004" deep) into the surface of the bore

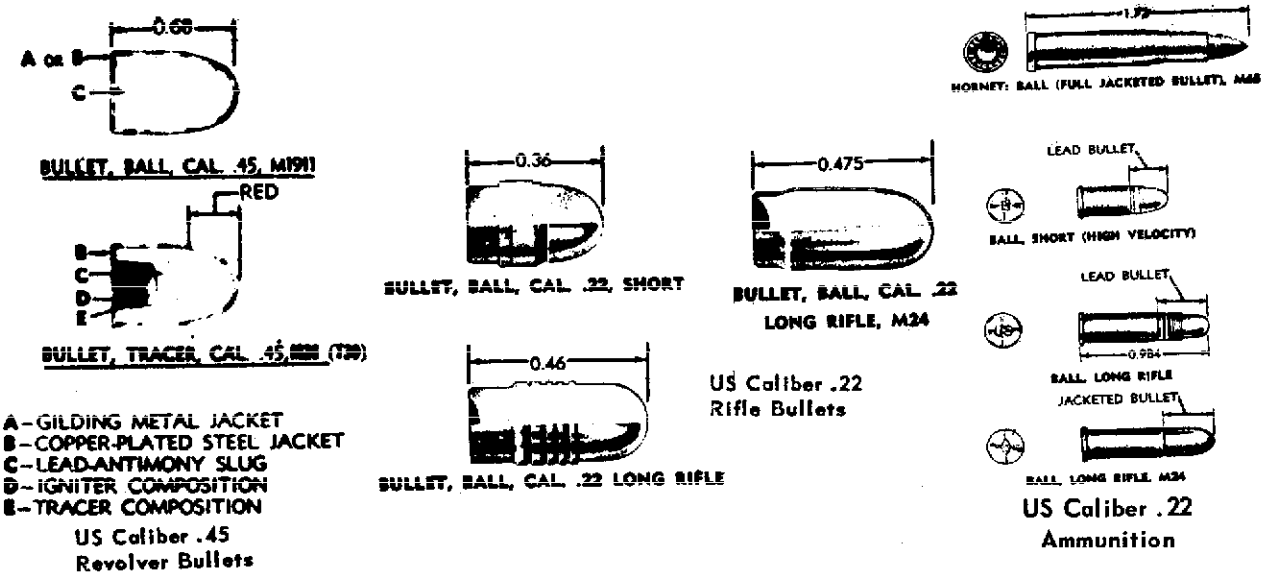
**B)Bullets, Metal Jacketed.** Naked lead(or lead alloy) bullets are not suitable for use in high -velocity or in automatic weapons. Only jacketed bullets should be used for these. Such bullets consist, in general, of a core(lead alloy) enclosed by a gilding metal(Cu 90 & Zn 10%) jacket or a steel jacket either copper-plated or covered with a thin layer of gilding metal. A *cannelure*(or annular knurl) is rolled or cut into the jacket to provide a recess into which the mouth of the cartridge may be crimped during assembly. The cannelure also serves to hold the jacket and core together more firmly. Cal .30 carbine and cal .45 pistol, revolver or sub-machine gun bullets do not have a cannelure since they are held by their tight fit in the cartridge case. The diameter of a jacketed bullet generally should not be more than 0.001" greater than the bore diam between grooves(see Note under Lead Bullets)

The body of a metal-jacketed bullet is cylindrical in shape with the nose either round, as in the carbine, pistol or revolver bullets, or ogival(curved taper) as in all service rifle and machine gun bullets. The length of ogive or taper for cal .30 and .50 bullets is ca 2½ calibers. The base may be "square"(cylindrical) or"boattailed"(having a conical taper). A special type of bullet is the "wad-cutter" or "mid-range" which is entirely cylindrical and has a square front in order that it may cut the target cleanly (Ref 8,pp 66-7). All US bullets are required to withstand storage under specified conditions and to function at the target betw -65° and +170°F(-54°and 76.7°C)(Ref 7,p 73)(See Figs)

Jacketed bullets may be subdivided into the following classes: ball, ball hornet, armor -piercing(AP), incendiary(I) & armor-piercing




**Typical Bullet & Cartridge Case Assembly**



-incendiary(API), high-explosive-incendiary(HEI), tracer(T) & armor-piercing-tracer(APT) and armor -piercing-incendiary-tracer(APIT)

a)*Ball Bullets* are intended for use against personnel and light material targets. They will usually go through an animal or man without tearing a jagged hole. The most common sizes used in the US are calibers .30(rifles and carbines) and .50(rifles and machine guns). These bullets have long, ogived noses and flat bases. There are also cal .45 revolver bullets which are roundnosed(Ref 8,p 67 & Ref 13,p 81)

b)*Ball, "Hornet" Bullets* are 45-grain guilding metal, full-jacketed, elongated bullets authorized for use in cal .22 "survival" rifle M4 and in the upper barrel of the cal .22/.410-gage survival rifle-shotgun M6, designed for shooting small game for food purposes(Ref 13,p 81 & Ref 17,p 38). The bullet is called "hornet" because its flight is accompanied by buzzing similar to that of a hornet and because, when shot its impact feels like a sting(Ref 16)

c)*Armor-Piercing(AP) Bullets* are intended for use against armored aircraft & vehicles, light concrete shelters and similar bullet-resisting targets. AP bullets consist usually of a gilding-metal jacket surrounding a tungsten -chromium or magnesium-molybdenum steel core. The cal .30 bullet has a point filler of lead and a gilding metal base filler between the core and the jacket, whereas the cal .50 bullet has only lead-antimony alloy(Pb 90 & Sb 10%) filler. The nose of AP bullets is a long, slender ogival type to lessen retardation due to air resistance. The nose is slightly flattened at the tip to provide better penetrating power(the width of the flattened tip is called the *meplat*). The base of the bullet is given a slight "boattail"(qv) shape in order to prevent breakage of the core during penetration of the armor as well as to reduce frictional air resistance during flight. It is usually required that AP bullets penetrate armor plate approx 1½" thick without breaking them into pieces. Both types of AP bullets have smooth cannelures in the jacket for crimping to the cartridge case(Ref 7,p 73-5; Ref 8,p 67 & Ref 13,p 81)

d)*Incendiary(I) and Armor-Piercing Incendiary (API) Bullets* are intended to initiate fires in aircraft fuel tanks, ammo and expls containers. Originally the bullets were designed on the same principal as the ball bullet, except that they contained a small quantity of an incendiary mixt in the nose. Later, when AP bullets replaced ball bullets for aircraft and antiaircraft use, it was decided to design a bullet which would penetrate light armor and ignite inside the target. The result of this design was the API bullet. A typical bullet contains a core of incendiary mixt and a Pb-Sb alloy slug at the base. A hollow steel cylindrical body or a clad steel container may be inserted within the jacket and before the base slug. Cal .30 and .50 incendiary bullets M1 are provided with two knurled cannelures

According to Ohart(Ref 7,p 76), the Amer cal .50 API bullet used during WWII contained 15 grains(ca .97g) of incendiary mixt of $Ba(NO_3)_2$ with Al/Mg alloy, placed in the nose of the bullet. The mixt was ignited by heat generated on impact of the bullet against a target. This caused it to tear open the gilding metal jacket and to scatter the incendiary mixt inside the target. The usual burning time of this mixt was from 10 to 40 msecs. A more effective API bullet was the cal .50 M23(Ref 7,p 76)(See also Ref 8,p 67 & Ref 13,pp 81-2)

e)*High-Explosive-Incendiary(HEI) Bullets* contain a chge of incendiary compn in the nose and a chge of HE in the center of the bullet(Ref 13,p 81)

f)*Tracer(T) and Armor-Piercing-Tracer(APT) Bullets.* It is often important to be able to observe the entire trajectory of the projectile, especially when firing at aircraft or other rapidly moving object. Machine guns on planes usually fire a proportion of tracer bullets, which leaves a trail of smoke and sparks easily seen by day or night

According to Marshall(Ref 2,p 564), the first modern tracers were devised in Germany in 1909 by J.B.Semple

At present, there are two types of tracer bullets. In the 1st type, part of the lead core at the base end is replaced by a tracer compn, such as $SrO_2$+ $Sr(NO_3)_2$+ Mg and an ignition compn, such as $BaO_2$+ Mg or $SrO_2$ + Mg. These substances are pressed into the bullet at ca 7000 psi(4900kg/cm$^2$) with a step punch(plunger). The base(which is flat and not tapered) is plugged by a fusible alloy which melts instantly on contact with propellent gases when the chge is fired

The 2nd type of tracer(APT) bullet is similar to the AP bullet except that the rear part of the steel core is replaced by tracer and igniter compns. The length of the trace is ca 1200yds for cal .30 and 1800yds for cal .50 bullets. A longer-range trace, 2500yds, used in some cal .50 bullets, contains a slow-burning tracer mixt of $Sr(NO_3)_2$, $KClO_4$ and Mg. In all

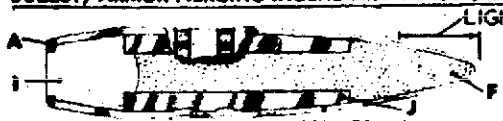
BULLET, BALL, CAL .50, M2

BULLET, ARMOR-PIERCING, CAL .50, M2

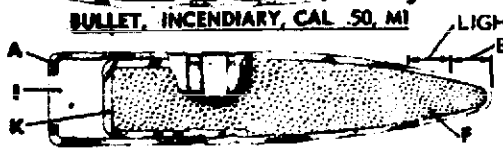
BULLET, ARMOR-PIERCING-INCENDIARY, CAL .50, M8

BULLET, ARMOR-PIERCING-INCENDIARY, CAL .50, T49

BULLET, ARMOR-PIERCING-INCENDIARY-TRACER, CAL .50, M20




BULLET, INCENDIARY, CAL .50, M1

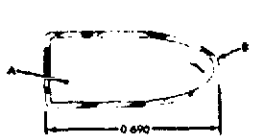



BULLET, INCENDIARY, CAL .50, M23

A—GILDING METAL JACKET
B—STEEL CORE
C—LEAD-ANTIMONY POINT FILLER
D—HARDENED ALLOY STEEL CORE
E—LEAD-ANTIMONY BASE FILLER
F—INCENDIARY MIXTURE
G—IGNITER CMPOSITION
H—TRACER COMPOSITION
I—LEAD-ANTIMONY SLUG
J—STEEL BODY
K—GILDING METAL CLAD STEEL CONTAINER

US Caliber .50 Bullets

BULLET, TRACER, CARBINE, CAL .30, M16

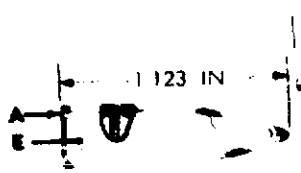



BULLET, BALL, CARBINE, CAL .30, M1

A—LEAD-ANTIMONY SLUG
B—GILDING METAL JACKET
C—GILDING METAL CLAD STEEL JACKET
D—IGNITER COMPOSITION
E—TRACER COMPOSITION

US Caliber .30 Carbine Bullets

BULLET, TRACER, CARBINE, CAL .30, M27 (T43)



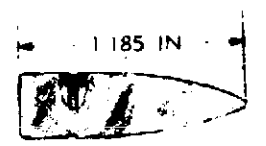

BULLET, BALL, CAL .30, M2

BULLET, ARMOR-PIERCIN CAL .30, M2

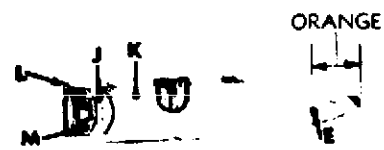
BULLET, INCENDIARY, CAL .30, M1

BULLET, ARMOR-PIERCI CAL .30, M14

BULLET, TRACER, CAL .30, M1

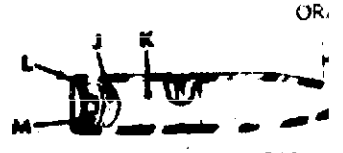



BULLET, BALL, FRANGIBL CAL .30, M22



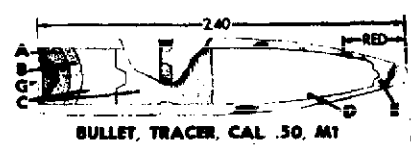

BULLET, TRACER, CAL .30, M25 (T10)

A—GILDING METAL JACKET
B—HARDENED ALLOY STEEL CORE
C—GILDING METAL BASE FILLER
D—LEAD "T" SHOT POINT FILLER
E—LEAD-ANTIMONY SLUG
F—STEEL BODY
G—LEAD SHOT #4 BODY FILLER




BULLET, TRACER, CAL . M25 (T72E1)

H—INCENDIARY COMPOS
J—TRACER COMPOSITIO DIM
K—TRACER COMPOSITIC BRIGHT
L—GILDING METAL CLA STEEL JACKET
M—IGNITER COMPOSITIC




BULLET, TRACER, CAL .50, M1

BULLET, TRACER, CAL .50, M10

BULLET, TRACER, CAL .50, M17

BULLET, TRACER, HEADLIGHT, CAL .5

A—IGNITER COMPOSITION
B—SUB-IGNITER COMPOSITION
C—TRACER COMPOSITION
D—LEAD-ANTIMONY SLUG
E—GILDING METAL JACKET
F—GILDING METAL CLAD STEEL JACKET
G—GILDING METAL CLOSURE

US Calibe Bullet

tracer bullets the light(usually red, but sometimes green) is visible, day and night, only from behind and not from the sides in order not to be visible to the enemy. As the light in some tracers is so strong that it can momentarily blind the gunner in night firing, the so-called "night tracer" was developed. The essential part of such a tracer is the "dim igniter", which contains $SrO_2$, Mg & Ca resinate. It should be noted that the heat developed by some tracers is so great the they may also function as incendiaries

In order to simulate a ball of fire and to make the enemy think he is under fire from much larger caliber weapons than small arms, the std cal .50 M1 tracer bullet is modified by replacing the usual igniter and tracer compns by a large amt of igniter compn alone($SrO_2$+ Mg). Although such compns burn for only 600yds, the intensity of light is about 3 times the usual intensity and is visible in all directions(Ref 2a,p 198; Ref 7,pp 77-8; Ref 8,p 68 & Ref 13,pp 81-2)

g)*Armor-Piercing-Incendiary-Tracer(APIT) Bullets* are similar to armor-piercing incendiary (API) bullets, but in addition have a tracer compn in the base end of the bullet(Ref 8,p 68 & Ref 13,p 81)

Illustrations of typical US caliber .30 and .50 bullets are included

*Refs:* 1)W.W.Greener, "The Gun and Its Development", Cassell, Potter, Galpin & Co, London(1881), 109-13,116-18,147,152-3,170,176, 180 & 188-91 2)Marshall **2**, (1917), 564 2a) Marshall **3**(1932), 176 & 198 3)Hayes(1938), 656-62 4)M.M.Johnson & C.T.Haven, "Ammunition", Morrow & Co, NY(1943), 21-3 5)J.R.Newman, "The Tools of War", Doubleday, Doran & Co, NY(1943) 6)Anon, "Ammunition Inspection Guide", TM **9-1904** (1944), 185,195-6,203,210-11 & 217 7)Ohart (1946), 73-8 8)Anon, "Small Arms Ammunition", TM **9-1990**(1947), 65-8,80,84,86,92,107 & 119-20 9)EncyclBritannica **4**(1952), 372 10)Ibid **20** (1952), 802-13(under Small Arms) 11)Anon, "Fundamentals of Small Arms", TM **9-2205**(1952), 32-4 12)B.R.Lewis, Ordn **38**, 947-9(1954)(Expl bullets used during Amer Civil War) 12a)J.F.C. Fuller, "A Military History of the Western World", Funk & Wagnalls, NY, v **2**(1955), 49, Footnote 1 12b)W.Y.Carman, "A History of Firearms", StMartin's Press, NY(1955), 89-156 & 165-79 13) Anon, "Ammunition General", TM **9-1900**(1956), 73-83 14)H.C.Logan, "The Cartridges", Stackpole Co, Harrisburg, Pa(1959), 183-6 15) Anon, "Platzpatrone aus Kunstoff", Explosivst **1961**, No 4,84 16)A.B.Schilling, PicArsn, Dover, NJ; private communication(1961) 17)Anon, "Small-Arms Ammunition", TM **9-1305-200**(1961), 26-38

**Bullets, Armor-Piercing(AP), Armor-Piercing -Incendiary(API), Armor-Piercing-Incendiary -Tracers(APIT) and Ball Bullets.** See under BULLETS

**Bullets, Blank and Dummy.** In *blank* ammo, which is used for simulated fire in maneuvers and in firing salutes & signals, the bullet is replaced by a wadding(such as paper) sealed in the mouth of the cartridge case contg a small chge of propInt(such as EC powder). In *dummy* ammo, which is used in practice for loading weapons and to simulate firing, a bullet(metallic, wooden or plastic) is inserted in the cartridge case contg no primer and no propInt

*Refs:* 1)Ohart(1946), 65 & 80 2)Anon, "Ammunition General", TM **9-1900**(1956), 82 3)Merriam-Webster's(1961), 230

**Bullets, Dumdum** were either soft-nosed bullets or standard bullets with vertical cuts made in their points so that they expanded upon hitting a target. When such bullets entered a body, the expansion usually resulted in fatal injuries due to the shattering of bones and tearing huge gaps in vital organs. These bullets were named for the Dumdum Arsenal, near Calcutta, India, where the British manufd them during the Boer War(1899-1902). Although prohibited by the Second Hague Conference for use in warfare, dumdums have occasionally been used during the 20th century by some nations

*Refs:* 1)"The Modern Encyclopedia", W.H.Wise & Co, NY(1947), 404 2)EncyclBritannica **7**(1952), 729 3)Merriam-Webster's(1961), 700

**Bullet Sensitivity Test.** See under BULLET TESTS

**Bullets, Explosive.** See under BULLETS, Historical

**Bullets, Frangible.** The caliber .30 frangible, ball bullet M22 used for outdoor firing practice, consists of a 50/50 blend of lead and bakelite. The cartridge is of brass, bottlenecked in shape. The bullet disintegrates on contact

with the target without injuring personnel
*Ref:* Anon,"Small-Arms Ammunition", TM **9-1305-200**(1961), 46-7

**Bullets, High-Explosive-Incendiary.** See under BULLETS

**Bullets, High-Pressure Test of.** See under CARTRIDGE, AMMUNITION

**Bullets, Incendiary.** See under BULLETS

**Bullet Splash.** It is the dispersion of finely divided or melted metal produced by a bullet upon impact with armor plate or other hard objects
*Ref:* Glossary of Ord(1959), 50

**Bullets, Shell.** Same as Bullets, Explosive

**Bullets, Spotter-Tracer.** The caliber .50 spotter-tracer bullet has a gilding metal jacket contg an incendiary chge in an Al-alloy container, and a tracer and igniter compn in a steel container. The ctge case is of brass. Upon contact with a target, the bullet will produce a flash and a light puff of smoke. It is used in cal .50 rifle for spotting the target for the gunner before firing the 106-mm rifle, M40
*Ref:* Anon, "Small-Arms Ammunition", TM **9-1305-200**(1961), 60

**Bullets, Tracer.** See under BULLETS

**BULLET TESTS.** Because a modern bullet is an integral part of a cartridge, its examination for defects is conducted at the same time as the cartridge is examined. The following tests concern only bullets:

**I)Bullet Fit(Jump) Test for Caliber .45 Ammunition.** When cal .45 ammo is fired in a revolver, recoil of the weapon tends to cause the bullets in the unfired cartridges to move forward and, if the bullets are not held tightly in postion in the cartridges cases, they can jam the cylinder and prevent it from revolving. The test described in Ref 9,p 5 has the purpose of determining whether or not the ammo for cal .45 jams the mechanism of a revolver when fired

**II)Bullet Impact Test; Bullet Frictional Impact Test; Bullet Sensitivity Test or Rifle Bullet Test**(Called *Shooting Test* in Ref 1). The purpose of this test is to determine to what extent various ammunition(especially bombs, which are usually thin-walled) or explosives which are packed in regulation containers are safe against the effect of small arms fire. In the methods described below expls are subjected to a combination of impact and friction produced when bullets hit them and then penetrate

*A)US Bullet Impact Method for Testing Explosives.* In this method, also called *Pipe Nipple Bomb Test,* a sample of the expl to be tested is loaded into a pipe nipple 3" long, 2" nominal diam and with 1/8" wall thickness. The nipple is cut from standard black iron pipe and is threaded at both ends to receive std 2" pipe caps. For press loading, the nipple without caps is loaded with ca 0.5lb of expl at the desired pressure; the threads are cleaned and vaselined and the caps assembled to the nipple to be held by at least two threads at each end. For cast-loading, one end of the nipple is closed with a cap and the molten sample(ca 0.5lb) is poured into the assembly. After the expl has cooled it is faced off flush with the end of the nipple. The threads are then cleaned and vaselined before the 2nd cap is screwed on the nipple to be held by at least two threads. The resulting loaded assembly is called a bomb. Once the caps are assembled, no attempt should be made to remove them and if there is any doubt about the contents of the bomb or its method of loading, the bomb should be destroyed

The correctly-assembled bomb is placed in an upright position on a stand which is located 90ft(ca 27.5m) from the muzzle of a cal .30 std infantry rifle rigidly supported in a barricade. Five or more bombs are usually prepd for each expl to be tested. Each of these bombs is subjected to the impact of one bullet(usually Ball, M2) fired in such a way that it passes through the bomb entirely below the upper cap and above the bottom cap and as close to the longitudinal axis as possible. The observed results of the bullet impact may be described as follows: a)Unaffected- no visible or audible indication of action b)Smoke(visible fumes or vapors) or burning(visible flash, flame or glowing) and c)Detonation, which can be partial(weak sound, smoke and/or flame; cracking of the bomb or bursting into very large pieces leaving a large amt of unconsumed expl) and complete(loud report, smoke and/or flame; complete bursting of the bomb into a large number of small fragments, leaving no unconsumed expl)(Ref 5,p 4; Ref 10,p 31; Ref 15,p 49 & Ref 16,pp 8-9)

The table given on pages B335-38 lists bullet

sensitivity values detd in the US for several expls, most of which are suitable for military purposes

The possibility of using cal .50 bullets for some expls which cannot be detonated or are difficult to detonate with cal .30 bullets was investigated during WWII at the Explosive Research Laboratory, Bruceton, Pa. Results of this investigation were reported in Ref 4,pp 14-16

*B)US Bullet Impact Method(Modification).* According to Stein & Pollack(Ref 16,p 1), the nipple bomb described above is not very satisfactory because the bullet strikes the curved surface thereby introducing undesirable variables which are inherent in a curved surface. To eliminate this problem a new bomb was designed which presents a flat surface perpendicular to the line of fire. This new bomb, however, retains a major deficiency of impact testing in that the explosive reaction is only described qualitatively in terms of detonation(complete or incomplete), burning, smoke,or unaffected. The new bomb consists of a metal cylinder 3" long and 2" diam. The ends of the bomb are closed by two flat plates, 2.5" wide by 4" long, which are attached to each other by means of two bolts and nuts. For cast loading, one of the plates is welded prior to loading the cylinder while the other plate is bolted after loading. For press loading, both plates are attached by means of 2 bolts and nuts to the ends of the cylinder after it has been loaded with ca 5 lb of expl. Each bomb is then placed on a stand in such a manner that the plate of one end faces the muzzle of the rifle. The results are reported as in Method A

This test may also be conducted by using cover plates of various thicknesses and by varying the length of the explosive column. For example, increasing the cover plate thickness from 0.250" to 0.375" increases the percentage of detonations from 94 to 100 for 50/50 Pentolite, from 31 to 50 for Composition B and from 60 to 90 for 67/33 Baratol. When 80/20 Tritonal was used, however, the % decreased from 50 to 0. An increase in percentage of detonations was observed also for some expls when the length of the expl column was increased from 1" to 2" and then to 3"

*C)Disc Method of Hercules Powder Company.* In this test procedure, the expl is loaded into steel pipe bombs 1" or 2" in diam and of varying wall thickness from 1/8 to 1/4". Instead of the usual screw cap, a base plate can be welded to the bomb, or omitted, and the assembly can be backed by a steel plate or block. Finally, a metal disc (of varying thickness) through which the bullet must pass is placed against the expl at the front end of the bomb. This assembled container is called a "disc bomb". The bullet is fired lengthwise into the chge of expl

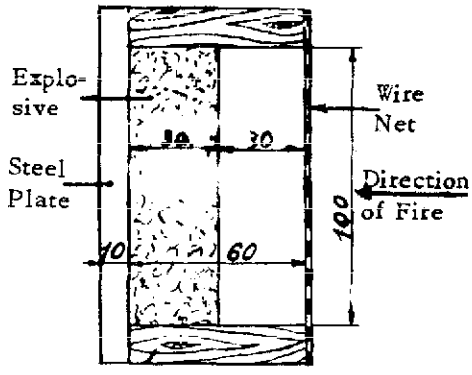
A modification of this disc bomb involves use of a pipe nipple(as in the US Method A) capped at one end only and covered with a steel disc over the other end of the expl chge. The bullet is fired thru the disc, lengthwise, into the chge with the capped end backed by a steel block

Test results showed that even cast TNT could be detond fairly consistently with a 220-grain bullet but less consistently with 172-grain SP(soft point) or 166-grain AP bullets. Flaked or grained TNT and cast pentolite could also be detonated consistently(Ref 5a,pp 2-4)

*D)Bullet Test, French Method.* This test is more rigid than the US methods described above and is more or less quantitative. The test was developed and used at the Laboratoire de la Commission des Substances Explosives and also used in other labs. The test is conducted with an expl placed in a square box made by attaching a wooden frame, 80 x 80mm & 60mm high, with 12-15mm wall thickness, to a square steel plate 10mm thick. A charge of HE to be tested is cast or compressed in the box to the exact height of 30mm. It takes betw 300 & 500g of expl(depending on the desired density) to fill the box to that height. The open end of the box is then covered with a screen made of thin wires. After a similar screen has been placed in front of the muzzle of the rifle, the box is set on one side with the screen toward the rifle and located at exactly 25m from the other screen and parallel to it. After connecting electrically each screen to a chronograph(such as LeBoulangé or Sadir-Carpentier), the rifle is fired using a truncated brass bullet(balle D en laiton), cal 8mm and weighing 8.1g. The bullet, after passing through the screen and 30-mm layer of explosive, strikes the steel plate but does not pierce it, thus remaining inside the box. For bullet velocities ranging from 210 to 840m/sec the Lebel Rifle, Model 1884, is used, whereas for higher velocities more modern weapons are required. Propellant known as "poudre $BFP_1$" is used in these tests. Variations in velocities are achieved by changing the wt of proplnt in the cartridge case. In these the highest velocity at which no detonations take place and the lowest velocity

required to cause complete detonation are detd. In the case of weak expls, such as DNT or some mining expls, the size of the box used is 100 x 100mm and 60mm high, but the test is the same(Refs 12,13 & 14)

FRENCH BULLET TEST




Wooden Frame
12–15 mm Thick

The table on page B339 gives results of these tests for some expls

*E)Bullet Impact Test Described by Colver.* In the test briefly outlined by Colver(Ref 1,p 647), the explosive is packed in cases which are arranged in a longitudinal row at various distances from a rifle. The minimum distance at which an expl detonates is noted as are the number of shots fired, the thickness of the layer penetrated and the velocity of the bullet. The shorter the distance and the larger the number of required shots to cause detonation, the less sensitive is the expl. Loosely-packed expls are usually more sensitive than those packed in cartridge form

*F)US Bullet Impact Test for Bombs.* In this test cal .30 AP, cal .50 AP, tracer and ball ammo as well as 20mm AP & HEI shells are fired at service muzzle velocity and at a range of 100 to 300yds, against loaded but unfuzed bombs. A minimum of 10 single shots, if possible, are fired at each bomb and an undamage surface is turned toward the rifle for each shot. In addition, a sustained burst is fired at one location on the bomb body. At least the cal .50 AP & tracer and 20mm AP & HEI are to be fired; use of other bullets is optional. Observation should be made for burning, low- or high-order detonation, flash intensity, smoke density and smoke color. When a fire results from an impact, the observations should include the time of burning, color of flame, evidence of scorching and color of smoke (Ref 17)

**III)Bullet Penetration Test**(also called Bullet Impact Test). This test is conducted to determine the ability of armor-piercing bullets to penetrate or perforate when fired at armor plate. This is usually done by firing at 100yds against an armor plate target properly mounted and supported. The angle of impact should be 85 to 90 degrees between the longitudinal axis of the bullet and the plate(Ref 11,p 42)

**IV)Bullet Pull Test.** The purpose of this test is to determine if a bullet is properly held in a cartridge case. The test is conducted in an apparatus which registers the force required to pull the bullet from the cartridge case. Following are the required bullet pull forces for different calibers of ammo: a)Cal .22 long rifle- not less than 28lbs b)Cal .30 rifle and carbine- not less than 45lbs c)Cal .45 revolver- not less than 40lbs and d)Cal .50 rifle and machine gun- not less than 200lbs(Ref 11,p 44)

**V)Bullet Stripping Test.** In this test it is determined whether or not the jackets of bullets strip from the core during flight(Ref 11,p 42)

**VI)Bullet Tracer Test.** In this test, tracer ammo is fired from a machine gun and the number of shots failing to trace the required distance is recorded. Also are recorded the number of muzzle bursts, blinds, or other erratic functionings(Ref 11,p 42)

*Refs:* 1)Colver(1918), 647 2)W.R.Tomlinson, Jr, "Development of Explosive of High Brisance", PATR **1170**(1942)(Cyclotol contg RDX 30 & TNT 70% was found to be insensitive to rifle bullet impact, whereas Cyclotol contg RDX 60 & TNT 40% with 1% wax added burned completely in one of five trials) 3)W.R.Tomlinson, Jr, "Special Tests of Sensitivity of TNT", PATR **1217**(1942)(Sensitivity to rifle bullet impact of liquid TNT's is greater than that of solid material provided the liquid is confined to such a degree that it cannot move under impact due to its incompressibility, and thereby dissipate the energy of impact translationally) 4)D.P. MacDougall et al, "Studies of the Sensitivity of Explosives to Bullet Impact", OSRD **3149**(1943) (The testing of ordinary HE's with cal .50 Ball, M2 ammo is briefly discussed and compared with analogous tests made with cal .30 Ball, M2 ammo. Next, the testing methods found appropriate for aluminized expls are discussed and finally, tests for typical demolition expls to the impact of incendiary and tracer bullets are described) 5) W.R.Tomlinson, Jr, "Compilation of Rifle Bullet

## Table III

### Rifle Bullet Impact Sensitivity of Explosives Tested in 1- or 2-inch Pipe Nipples with Caliber .30, Ball, I

### Unless Otherwise Stated

| Explosive | Diam of Nipple inches | Method of Loading | Density of Loading | Number of Trials | % Unaffected | % Smok or Bum |
|---|---|---|---|---|---|---|
| Amatol-80/20(AN 80 & TNT 20%) | 2 | Cast | 1.50 | 5 | 100 | - |
| | 1 | Pressed | 1.60 | 10 | 100 | - |
| Amatol 50/50(AN 50 & TNT 50%) | 2 | Cast | 1.55 | 5 | 100 | - |
| Ammonium Nitrate(AN) | 2 | Pressed | 1.2 | 10 | 100 | - |
| Ammonium Perchlorate | No information | | | | | |
| Ammonium Picrate(AP)(Explosive D) | 2 | Pressed | 1.50 | 10 | 70 | 3 |
| | 1 | Pressed | 1.2 | 5 | 100 | - |
| | * | Pressed | ? | 10 | 70 | 3 |
| Baratol-67/33(Ba nitrate 67 & | 2 | Cast | 2.55 | 10 | — | 5 |
| TNT 33%) | * | ? | ? | 10 | — | 4 |
| Baronal(Ba nitrate 50, TNT 35 & | 1 | Cast | 2.32 | 9 | 11 | 5 |
| Al 15%) | | | | | | |
| Black Powder(K nitrate 75, | No information | | | | | |
| Charcoal 15 & sulfur 10%) | | | | | | |
| Blasting Gelatin | See table under item D(French Method) | | | | | |
| Borotorpex(RDX 46, TNT 44 & | 2 | Cast | ? | 10 | — | 5 |
| B powder 10%) | | | | | | |
| Compositon A, Aluminized(RDX | 1 | Pressed | 1.6 | 11 | 91 | 9 |
| 73, Al powder 18 & wax 9%) | | | | | | |
| Composition A-3(RDX 91 & | 2 | Pressed | 1.59 | 5 | 100 | - |
| beeswax 9%) | 1 | Pressed | 1.59 | 20 | 95 | - |
| Composition B(RDX 60 & TNT 40 | 2 | Cast | 1.68 | 60 | 80 | 4 |
| with 1 % wax added) | 2 | Cast | 1.68 | 20 | 20 | 4 |
| Composition C(Brit PE-2)(RDX | 2 | Hand-tamped | 1.58 | 5 | 100 | - |
| 88.3 & non-expl oily plasticizer, contg 0.6% lecithin, 11.7%) | | | | | | |
| Composition C-2(RDX 78.7, TNT 5.0, DNT 12.0, MNT 2.7, NC 0.6 & solvent 1.0%) | 2 | Hand-tamped | 1.52 | 5 | 80 | - |
| Composition C-3(RDX 77, tetryl 3, | 2 | Hand-tamped | 1.57 | 5 | 60 | - |
| TNT 4, DNT 10, MNT 5 & NC 1%) | * | | ? | 10 | 80 | 1 |
| Composition C-4 [RDX 91, polyiso- | 2 | Hand-tamped | 1.59 | 5 | 80 | 2 |
| butylene 2.1, motor oil 1.6 & | * | " | ? | 10 | 60 | 4 |
| di(2-ethylhexyl) sebacate 5.3%] | 2 | Pellets | ? | 3 | — | - |
| Cordite | 1 | Cast | ? | 20 | 30 | 3 |
| Cyclofive(RDX 53 & Fivonite 47%) | See Cyclotrimethylenetrinitramine | | | | | |
| Cyclonite or RDX | No information | | | | | |
| Cyclotetramethylenetetranitramine(HMX)(beta) | | | | | | |
| Cyclotol-75/25(RDX 75 & TNT 25%) | 2 | Cast | 1.71 | 10 | 30 | 4 |
| | * | ? | ? | 10 | 30 | - |
| Cyclotol-70/30(RDX 70 & TNT 30%) | 2 | Cast | 1.71 | 10 | 40 | - |
| | 2 | ? | ? | 10 | 10 | 5 |

*Loaded in bomb No 2 as described in Ref 16

## Table III

### Rifle Bullet Impact Sensitivity of Explosives Tested in 1- or 2-inch Pipe Nipples with Caliber .30, Ball, Unless Otherwise Stated

| Explosive | Diam of Nipple inches | Method of Loading | Density of Loading | Number of Trials | % Unaffected | % Smoke or Burned |
|---|---|---|---|---|---|---|
| Cyclotol-60/40(RDX 60 & TNT 40%) | 2 | Cast | 1.68 | 20 | 15 | 25 |
| Cyclotrimethylenetrinitramine (cyclonite or RDX) | 2 | Pressed | 1.65 | 5 | – | – |
| | 1 | " | 1.6 | 5 | – | – |
| Cyclotrimethylenetrinitrosamine(R Salt) | See table under item D(French Method) | | | | | |
| DBX(RDX 21, AN 21, TNT 40 & Al 18%) | 1 | Cast | 1.65 | 11 | 55 | 45 |
| Dentex(RDX 48, DNT 34 & Al powd 18% with 0.7% wax added) | 2 | Cast | ? | 10 | 30 | 70 |
| Diethanoldinitramine Dinitrate (DINA) | 2 | Cast | ? | 7 | 57.1 | 14 |
| Diethyleneglycol Dinitrate (DEGDN) | 1 | Liq | 1.38 | 3 | – | – |
| Dinitrodi(β-nitroxyethyl)-oxamide(NENO) | 1 | Cast | ? | 5 | – | – |
| Dipentaerythritol Hexanitrate(DPEHN) | No information | | | | | |
| DNT | See table under item D(French Method) | | | | | |
| EDDN | See Ethylenediamine Dinitrate | | | | | |
| EDNA or Haleite | See Ethylenedinitramine | | | | | |
| Ednafive(EDNA 50 & Fivonite 50%) | 1 | Cast | ? | 25 | 60 | 36 |
| Ednatol-55/45(EDNA 55 & TNT 45%) | 2 | Cast | 1.62 | 15 | 93 | 7 |
| EMMET | See Trimethylolpropane Trinitrate | | | | | |
| Ethylenediamine Dinitrate (EDDN) | 1 | Pressed | 1.0 | 5 | 100 | – |
| Ethylenedinitramine(EDNA or Haleite) | 2 | Pressed | 1.60 | 5 | 20 | 20 |
| | 1 | " | " | 5 | 60 | – |
| Explosive D | See Ammonium Picrate | | | | | |
| Fivonite(Tetramethylolcyclopentanone Tetranitrate) | 1 | Cast | ? | 33 | 51.5 | 45 |
| Guanidine Picrate(GuP) | 1 | Pressed | 1.0 | 10 | 100 | – |
| H-6 | See Conf Ref 20,p 388 | | | | | |
| Haleite or EDNA | See Ethylenedinitramine | | | | | |
| HBX-1 and HBX-3 | See Conf Ref 20,pp 382 & 385 | | | | | |
| Hexanitrodiphenylamine(HNDPhA) | No information | | | | | |
| HMX | See Cyclotetramethylenetetranitramine | | | | | |
| HTA-3 | See Conf Ref 20,p 402 | | | | | |
| Mannitol Hexanitrate | No information | | | | | |
| Medium Velocity Dynamite(MVD) (RDX 75, TNT 15, starch 5, SAE No 10 oil 4 & Vistanex Oil Gel 1%) | 2 | Machine -tamped | 1.1 | 10 | 90 | 10 |
| Metriol Trinitrate | No information | | | | | |
| Minol-2(AN 40, TNT 40 & Al 20%) | 2 | Cast | 1.68 | 19 | 100 | – |

## Table III

### Rifle Bullet Impact Sensitivity of Explosives Tested in 1- or 2-inch Pipe Nipples with Caliber .30, Ba

### Unless Otherwise Stated

| Explosive | Diam of Nipple inches | Method of Loading | Density of Loading | Number of Trials | % Unaffected | % Sm or Bu |
|---|---|---|---|---|---|---|
| Minol-2(AN 40, TNT 40 & Al 20%) | ** | Cast | 1.68 | 10 | – | |
| MVD | See Medium Velocity Dynamite | | | | | |
| NENA | Same as β-Nitroxyethylnitramine | | | | | |
| NENO | See Dinitrodi(β-nitroxyethyl)oxamide | | | | | |
| Nitrocellulose(NC) | No information | | | | | |
| Nitroglycerine(NG) | 2 | Liq | 1.6 | 5 | – | |
| Nitroglycol(NGc) or Glycol Dinitrate | No information | | | | | |
| Nitroguanidine(NGu) | 2 | Pressed | 1.50 | 5 | 100 | |
| | 1 | Pressed | 1.0 | 10 | 100 | |
| Nitrostarch(NS) | No information | | | | | |
| Nitrostarch Demolition Explosive [NS(12.50%N) 49, Ba nitrate 40, MNN 7, p-MNA 3 & oil 1%) | 2 | Hand-tamped | 0.92 | 10 | 10 | |
| β-Nitroxyethylnitramine(NENA) | No information | | | | | |
| Octol-75/25(HMX 75 & TNT 25%) | See Conf Ref 20,p 429 | | | | | |
| PB-RDX | See Plastic Bonded RDX | | | | | |
| PE-2(Plastic Explosive-2)(Brit) | See Composition C | | | | | |
| Pentaerythritol Tetranitrate (PETN) | 2 | Pressed | 1.70 | 5 | – | |
| | 1 | Pressed | 1.6 | 2 | 50 | |
| Pentaerythritol Trinitrate(PETRIN) | See Conf Ref 20,p 440 | | | | | |
| Pentofive(PETN 50 & Fivonite 50%) | 1 | Cast | ? | 7 | – | |
| Pentolite-50/50(PETN 50 & TNT 50%) | 2 | Cast | 1.66 | 25 | 8 | |
| Pentonal(PETN 47, TNT 33 & Al 20%) | 1 | Cast | ? | 20 | 15 | |
| PETN | See Pentaerythritol Tetetranitrate | | | | | |
| PETRIN | See Pentaerythritol Trinitrate | | | | | |
| Picramide | See Trinitroaniline | | | | | |
| Picratol-52/48(PA 52 & TNT 48%) | 2 | Cast | 1.63 | 10 | 60 | |
| | * | ? | ? | 10 | 50 | |
| Picratol, Ammonium(Ammonium Picrate 53 & TNT 47%) *** | 1 | Cast | ? | 20 | 90 | |
| Picric Acid(PA) or 2,4,6 -Trinitrophenol | 1 | Cast | ? | 11 | 36.4 | |
| PIPE(PETN 81 & Gulf Crown E Oil 19%) | 2 | Pressed | 1.64 | 5 | – | |
| | 2 | Hand-tamped | 1.37 | 5 | 100 | |
| Plastic Bonded RDX(PB-RDX) | See Conf Ref 20,p 434 | | | | | |
| PLX(Nitromethane 95 & Ethylenediamine 5%) | 2 | Liq | 1.12 | 5 | 100 | |
| PTX-1(RDX 30, Tetryl 50 & TNT 20%) | 2 | Cast | 1.64 | 5 | 60 | |
| PTX-2(RDX 41-44, PETN 26-28 & TNT 33-28%) | 2 | Cast | 1.70 | 5 | 45 | |
| PVA-4(RDX 90-92, polyvinylacetate 8-6 & DBuPh 2%) | 2 | Cast | 1.60 | 5 | 20 | |

*Loaded in bomb No 2 described in Ref 16

**Loaded in 100-lb GP Bomb AN-M30(Ref 7a,p 19)

***Using cal .

## Table III

### Rifle Bullet Impact Sensitivity of Explosives Tested in 1- or 2-inch Pipe Nipples with Caliber .30, Ball, M Unless Otherwise Stated

| Explosive | Diam of Nipple inches | Method of Loading | Density of Loading | Number of Trials | % Unaffected | % Smoked or Burned |
|---|---|---|---|---|---|---|
| RIPE(RDX 85 & Crown E Oil 15%) | 2 | Hand-tamped | 1.37 | 10 | 100 | – |
| R-Salt | See Cyclotrimethylenetrinitrosamine | | | | | |
| Sevranite | See Table in item D(French Method) | | | | | |
| Shellite(PA 59 & 2,4-DNPh 50%) | 1 | Pressed | 1.6 | 5 | 100 | – |
| | 1 | Cast | ? | 10 | 100 | – |
| Silico-Minol(AN 40, TNT 40 & silicon powder 20%) | 1 | Cast | ? | 2 | 100 | – |
| Tetramethylolcyclopentanone Tetranitrate | See Fivonite | | | | | |
| Tetryl(2,4,6-Trinitrophenyl -N-methylnitramine) | 2 | Pressed | 1.6 | 10 | 40 | 30 |
| | 2 | " | 1.71 | 30 | 23 | 10 |
| | * | " | ? | 10 | 70 | 30 |
| Tetrytol-75/25(Tetryl 75 & TNT 25%) | 2 | Cast | 1.60 | 5 | 72 | – |
| Tetrytol-65/35(Tetryl 65 & TNT 35%) | 2 | Cast | 1.60 | 5 | 90 | – |
| TNT | See Trinitrotolunee | | | | | |
| Tolamite | See table under item D(French Method) | | | | | |
| Torpex-2(RDX 42, TNT 40 & Al 18%) | 2 | Cast | 1.81 | 5 | – | – |
| | * | ? | ? | 10 | – | – |
| | 2 | Flake | 1.3 | 4 | – | – |
| Torpex, German(RDX 20.5, TNT 57.7 & Al 21.8%) | 2 | Cast | | 10 | 50 | 25 |
| Tridite(Ammonium Picrate 80 & DNPh 20%) | No information | | | | | |
| Trinethylolpropane Trinitrate (EMMET) | 2 | ? | ? | 8 | – | – |
| Trimonite(PA 88-90 & MNN 12-10%) | 2 | Cast | 1.60 | 5 | 100 | – |
| Trinitroaniline(TNA) or Picramide | No information | | | | | |
| Trinitrophenol | See Picric Acid | | | | | |
| Trinitrotoluene(TNT) | 2 | Cast | 1.56 | 25 | 96 | 1 |
| | 2 | Cast | 1.56 | 45 | 71 | 22 |
| Tripentaerythritol Octonitrate(TPEON) | See Conf Ref 20,p 465 | | | | | |
| Tritonal(TNT 80 & Al 20%) | 2 | Cast | 1.72 | 25 | 40 | – |
| | 2 | ? | ? | 30 | 60 | – |
| | * | ? | ? | 10 | 50 | – |
| | ** | ? | ? | 10 | 40 | – |
| Veltex | See Conf Ref 20,p 470 | | | | | |

*Loaded in Bomb No 2 described in Ref 16

**Loaded in 100-lb GP Bomb AN-M30(Ref 7a,p 19)

**Table IV Rifle Bullet Impact Test by the French Method**

| Explosive | Density $g/cm^3$ | Bullet Velocity, m/sec | |
|---|---|---|---|
| | | Maximum for No Detonation | Minimum for Complete Detonation |
| PETN | 0.7 | 257 | 290 |
| RDX | 1.0 | 274 | 327 |
| Tetryl | 1.0 | 280 | 330 |
| PA | 1.0 | 370 | 393 |
| PA,cast | 1.65 | 1087 | No deton |
| R-Salt | 0.6 | 505 | 515 |
| TNT(Grade T) | 0.85 | 675 | 714 |
| TNT, cast | 1.6 | 1042 | No deton |
| TNT(Grade D) | 1.15 | 704 | 740 |
| NGu,needles | 0.6 | 781 | 793 |
| NGu,powdered | 0.9 | 833 | No deton |
| EDNA | 1.0 | 960 | 1040 (incomplete) |
| DNT | 1.0 | 1040 | No deton |
| PETN/Paraffin-97.5/2.5 | 0.75 | 355 | 396 |
| " " -95/5 | 0.70 | 471 | 515 |
| " " -90/10 | 0.65 | 657 | 666 |
| " " -85/15 | 0.70 | 819 | 833 |
| " " -82.5/17.50 | 0.70 | 1000 | No deton |
| PETN/MNN-95/5 | 0.70 | 390 | 396 |
| RDX/Paraffin-97.5/2.5 | 0.90 | 714 | 724 |
| " " -95/5 | 0.85 | 769 | 793 |
| " " -90/10 | 0.95 | 1063 | 1110 |
| RDX/Beeswax-92.5/7.5 | 0.95 | 833 | 847 |
| RDX/MNN | 1.1 | 431 | 463 |
| PETN/TNT-50/50 | 1.1 | 310 | 335 |
| " " " (cast) | 1.65 | 943 | 1042 |
| PETN/TNT-20/80 | 1.05 | 335 | 385 |
| " " " (cast) | 1.65 | 1063 | No deton |
| RDX/TNT-60/40 | 1.3 | 390 | 400 |
| " " " (cast) | 1.7 | 980 | 1000 |
| RDX/TNT-50/50 | 1.2 | 396 | 400 |
| " with 1% wax added | 1.0 | 616 | 641 |
| RDX/TNT-62/38 with 1% wax added | 1.0 | 543 | 547 |
| Tetryl/TNT-70/30(cast) | 1.55 | 1042 | No deton |
| AN/TNT-50/50 | 1.0 | 471 | 500 |
| " " (cast) | 1.30 | 1087 | No deton |
| AN/TNT-60/40 | 1.05 | 543 | 561 |
| AN/Sawdust-87/13 | 0.8 | 1111 | No deton |
| AN/Al powder-82/18 | 0.9 | 537 | 793 |
| AN/RDX-52/48 | 1.0 | 322 | 357 |
| AN/PETN-33.3/66.7 | 0.85 | 301 | 316 |
| AN/DNN-87.5/12.5 | 0.9 | 550 | 575 |
| Blasting Gelatin-95.5/7.5 | 1.5 | 280 | 357 |
| PETN/TNT/Al-40/40/20 | 0.95 | 266 | 297 |
| " " " " (cast) | 1.6 | 670 | 806 |
| RDX/TNT/Al-40/40/20 | 1.0 | 349 | 360 |
| " ,cast | 1.6 | 909 | 925 |
| AN/TNT/Al-40/40/20 | 0.95 | 337 | 364 |
| " " " " " (cast) | 1.2 | 781 | 833 |
| TNT/Al-85/15(cast) | 1.5 | 1087 | No deton |
| Comp C(Brit PE-2)(tamped) | 1.65 | 1021 | No deton |
| Comp C-2(tamped) | 1.7 | 1021 | No deton |
| Tolamite(NG 27.0, NC 1.0, DNT 9.5, cellulose 1.5 & AN 61.0%) | 1.5 | 316 | 337 |
| Sevranite No 1(PETN 48, Amm perchlorate 31, Al 3 & plasticizer 18%) | 1.55 | 333 | 347 |
| DNT/$NaClO_3$-28/72 | 1.2 | 301 | 337 |
| TNT/$NaClO_3$-38/62 | 1.3 | 254 | 294 |

*Note:* All expls were pressed except those marked "cast" or "tamped"

Impact Test Data of Military Explosives", Chemical Rept, Pic Arsenal, Dover, NJ(1943); published as section **2** in OSRD **3156**(1944) 5a) R.W.Lawrence & J.E.Meyers, "Sensitiveness of High Explosives to Rifle Bullets", Experiment Station, Hercules Power Co, Wilmington, Del (1944); published as secn **1** in OSRD **3156**(1944) 6)D.I.Hedrick, ' 'The Sensitivity to Projectile Impact of Explosives in Various Containers", Rept No **19-43**(1943), Naval Proving Ground, Dahlgren, Va ; published as secn **4**in OSRD **3156**(1944)(The thickness and material of the container play an important part in detg the action of impact. Thick cases offer considerable protection to the charge from cal .30 ball and 20mm HE projectiles. Against cal .30 AP bullets, TNT was the safest expl, but it gave a low-order deton upon impact by cal .50 AP bullet) 7)E.H.Eyster et al, "The Effect of Small Caliber Projectiles on HE Loaded Bombs and Shells", Rept of Aberdeen PG, published as secn **5** in OSRD **3156**(1944)(Rifle bullet tests were conducted with various bombs loaded with TNT or other HE's. In testing a 4000-lb LC M56bomb loaded with 50/50 Amatol, it was found that it could be detonated by impact of cal .50 bullets fired from a machine gun at a range of 300 yds; the same may sometimes be true with cal .30 AP bullets, also fired from a machine gun. Results of testing smaller bombs, such as 25- and 100-lb, loaded with TNT, 60/40-Sodatol, 80/20-Amatol, 60/40-TNN/TNT, 65/35-TNT/GuN and Tridite, are also reported) 7a)R.A.Connor et al, OSRD Rept **5406**(1945), 15 & 17-19(Rifle bullet test values for HBX, Minol-2, Torpex-2, TNT & Tritonal) 8)E.H.Eyster & W.H.Rogers "The Sensitivity of Explosives to Bullet Impact", OSRD **5745**(1945)(The rept deals with "ordinary" cast HE's, with ' 'ordinary" pressed HE's, with some sluminized expls and with some liquid expls. A German method of testing is briefly described on p 11) 9)Anon, "Ordnance Proof Manual", OPM 7-24, Aberdeen PG, Md(1945), p 5 10)Ohart(1946), 31 11)Anon, "Small Arms Ammunition", TM 9-1990(1947), 42-4(Bullet Stripping Test, Bullet Penetration Test, Bullet Fit Test and Bullet Pull Test are briefly described) 12)E.Burlot, MAF **23**, 185 (1949)(Detonation of ordinary expls by impact of solid projectiles launched at great velocities) 13)L.Médard & (?)Cessat, MAF **23**, 195-203(1949) (Comparison of behavior of various expls to impact of bullets) 14)A.LeRoux, MP **33**, 283-321(1951)(Sensitivity to bullet impact reported for military expls, such as PA, TNT, Tetryl, PETN & RDX; for mixts, such as PETN/TNT, RDX/TNT and for mining expls, such as Dynamite-gomme, Tolamite, Sevranite, Explosif O,Explosif N) 15)Anon, "Military Explosives", TM **9-1910**(1955), 49(Sensitivity to Rifle Bullet Impact ; 322-3, table 1) 16)S. Stein & M.E.Pollack, "Development of an Improved Rifle Bullet Impact-Sensitibity Test", PATR **2247**(1956) 17)Anon, "Ordnance Proof Manual", OPM **10-86**. Aberdeen PG, Md(1957),p 2 (Bullet impact tests for bombs) 18)H.Will & G.Silvestro, "Development of Method for Determining the Sensitivity of Explosives to Bullet Impact", Instrumentation Rept No TR **681-58**, PicArsn, Dover, NJ(1958) 19)W.R. Tomlinson, Jr, "Properties of Explosives of Military Interest", PATR **1740**, Revision 1(1958) by O.E.Sheffield 20)O.E.Sheffield, "Properties of Explosives of Military Interest", PATR **1740**, Supplement No 1(1958)(Conf) 21)W.H. Rinkenbach, Allentown, Pa; private communication(1961)

**Bull Goose or Goose.** Popular name for a US Air Force delta-wing air-breather, diversionary missile designed by the Fairchild Engine & Airplane Corp. The Goose is launched, together with real missiles or manned bombers to act as a decoy to attract enemy defense system devices(such as radar) away from the real missiles or bombers. It is powered by a Fairchild J-83 turbojet engine which produces ca 2000-pound thrust. The Ramo-Woolridge Corp provides the electronic countermeasures equipment carried in the Bull Goose

*Refs:* 1)Glossary of Ord(1959), 50 2)C.E.Davis, "The Book of Missiles", Dodd, Mead & Co, NY(1959), 52

**Bullpup Missile**(X-ASM-N-7). A US Navy air-to -surface missile manufd by the Glenn L. Martin Co(now Martin Marietta Corp), having a canard configuration and using an Aerojet General solid-propellant rocket. It was designed to be launched by attack aircraft from any position outside the effective range of enemy high volume ground fire and to provide sufficient accuracy to destroy small targets without excessive sorties and expenditure of large quantities of bombs and rockets. It carries a conventional warhead which is contact fuzed. A proximity fuze can also be used in it. The advanced versions of Bullpup are Bulldog and White Lance

*Refs:* 1)G.Merrill, "Dictionary of Guided Missiles and Space Flight", Van Nostrand, NY(1959), 104 and illustration facing p 59 2)Glossary of Ord(1959), 50 3)C.E.Davis, "The Book of Missiles", Dodd, Mead & Co, NY(1959), 30

**Bullseye Powder.** The following double-base propellant: NC(13.25%N) 60.0, NG 39.5 & DPhA 0.5%, in the form of circular flakes, diam 0.035" and thickness 0.005", was subjected during WWII at PicArsn to 65.5° Surveillance and to 120° & 134-5° Heat Tests. The results of these tests, reported by Rinkenbach(Ref 1), showed that this propint was of satisfactory stability. According to Westheimer et al(Ref 2), Bullseye Powder is manufd by Hercules Powder Co, Wilmington, Del. One of their Bullseye propints manufd during WWII was in the form of 7/8" sticks, which consisted of NC(13.25%N) 58.8,NG 40.0, EtCentr 1.0 & DPhA 0.2% with some carbon black added(Ref 3)
*Refs:* 1)W.H.Rinkenbach, PATR **1359**(1943), p 2 & table II 2)F.H.Westheimer et al, OSRD Rept **4758**(1945), p 10 3)G.D.Clift, private communication(1962)

**Bullseye Powder**(Modern). No info at our disposal

**Bullseye Modified.** Same as JPT Propellant

**Bumblebee.** A series of surface-to-air missiles sponsored by the US Navy and developed by various contractors under the technical direction of Johns Hopkins University, Baltimore, Md
*Ref:* DictyGuidedMissiles(1959), 104
*Note:* A series of confidential reports were issued on this subject by Johns Hopkins University, Baltimore, Md, Contract NOrd-7386

**BuMines or BurMines.** Abbrn for the Bureau of Mines(US)

**Bumper.** The code name of a high-altitude rocket involving the V-2/WAC-Corporal first and second stages

**Bumper Missile** is a two-stage rocket missile
*Ref:* DictyGuidedMissiles(1959), 104

**Bu-NENA.** Designation for N-(2-Nitroxyethyl) -butylnitramine described here as [1-(N -Butylnitramino)-ethan-2-ol]Nitrate under Butylaminoethanol and Derivatives

**Bunsen, Robert W. von**(1811-1899). A Ger chemist noted for gasometric and photometric researches and for various inventions, such as burner, valve, cell, clamp & funnel eudiometer. The first theory of the burning process of black powder was estabilished by him and simultaneously by a Russian chemist, L. Shishkoff. Bunsen lost the sight of his right eye due to the expln of cacodyl cyanide, which he discovered together with other derivs of cacodyl
*Refs:* 1)H.Goldschmidt, ZAngewChem **24**, 2137-40(1911)(Recollections of Robert Wilhelm Bunsen) 1a)C.Cranz, "Lehrbuch der Ballistik" **2**, Springer, Berlin(1926) 2)F.J.Moore, "A History of Chemistry", McGraw-Hill, NY(1939), 264-71 3)Hackh's(1944), 147 4)M.E. Serebryakoff, "Interior Ballistics", Moscow(1949), Abbreviated English translation for the US Navy by Dr V.A.Nekrassoff, Catholic University of America, Washington, DC(1954), 25 5)E.Farber, Edit, "Great Chemists", Interscience, NY(1961), 573-81

**Bunsen Valve.** A simple device which allows the air or vapor to escape from a closed container (such as a flask) but does not allow air to re-enter. It may be prepd in the following manner:

Insert a glass rod, 3mm diam and ca 6" long, into a piece of rubber tubing(perferably of pure gum) of 3mm bore, 2" long and 1.25mm wall. Cut, by means of a razor blade, a slot in the tubing ca 3/8" long and at an angle of 15-20° to the axis. Remove the glass rod and slip one end of the tubing onto a piece of glass tubing 2" long and ca 5mm OD. This is inserted in a rubber stopper fitting the flask or other container. Close the other end of the rubber tubing with a short piece of glass rod or a small stopper. Seal all joints with shellac and allow to dry

To test the valve, remove the glass tube from the rubber stopper of the flask and note if the slot allows passage of air when some pressure is applied. Then connect the tube to a water pump and see if it creates a vacuum
*Refs:* 1)Clift & Fedoroff **3**(1943), Chap II,p 13 2)Hackh's(1944), 888

**BuOrd.** Abbrn for the Bureau of Ordnance(US Navy)

**Buramine.** A butyl urea-formaldehyde resin manuf during WWII by the Sharples Solvent Co. It was employed in a butanol soln(65% concn) as

a binder in some molded composite proplnts. Eg: **218B**(Propellant): Buramine 5.1, Amm picrate 46.7, Na nitrate 46.7, "Santicizer 8" (plasticizer manufd by Monsanto Chemical Co) 1.5 & Ca stearate 0.4p
*Ref:* "Summary Technical Report of Division 8, NDRC" vol 1(1946), 96

**Bureau of Aeronautics**(BuAer), US Navy, established in 1921 and abolished in 1959. Its functions were transferred(with those of Bureau of Ordnance) to the Bureau of Naval Weapons(qv), effective July 1, 1960

**Bureau of Explosives**(BuExpl) or more fully, *Bureau for the Safe Transportation of Explosives and other Dangerous Articles.* The BuExpl was established by the American Railway Association in 1906, three years before the organization of ICC(Interstate Commerce Commission). In 1934, the AmRyAsso created through consolidation with other organizations, the "Association of American Railroads, Bureau of Explosives". The BuExpl makes inspections, conducts investigations and confers with manufactures and shippers of explosives and other dangerous materials, with the view of detg what regulations will afford the highest degree of safety(within reasonable limits) in packing and prepg these materials for shipping. The BurExpl thus became expert in the handling of expls and has thereby established its shipping regulations. Its inspectors are stationed throughout the US to observe, investigate and report upon shipping methods. The common carriers utilize the services of the BuExpl in enforcing regulations as well as in assisting shippers(Refs 1 & 2)

The BuExpl publishes various pamphlets, as well as shipping regulations, known as "Interstate Commerce Commission Regulations" (See Refs 3 & 4). These publications may be obtained by writing to T.C.George, Agent, 63 Vesey St, New York 7, NY
*Refs:* 1)US Chief of Ordnance, "Safety and Storage Manual for Explosives and Ammunition", OO Form No **5994**, Washington, DC(1928), secn 8 2)M.Newton, "The Bureau of Explosives", ChemInd, Dec 1944,pp 928-30 3)Sax(1957),secn 11 4)Agent T.C.George's Tariff No 13, "Interstate Commerce Commision Regulations for Transporting Explosives and Other Dangerous Articles by Land and Water in Rail Freight Service and by Motor Vehicle(Highway) and Water", New York 7, NY(Sept 15, 1960)(Supplements 1 & 2 added)

**Bureau of Mines**(BuMin or BurMines), US Dept of Interior, Washington 25, DC. Created in 1910 as part of the Dept of Interior, transferred in 1925 to Dept of Commerce and retransferred to Dept of Interior in 1934. The purpose of the BuMin is to design, promote methods for conservation and development of mineral resources and to assure healthful working conditions in the mineral industries. It also conducts research in technology of fuels, explosives, minerals, helium, etc. Its research on expls(mainly mining expls) is conducted at Pittsburg and at Bruceton, Pa. Results of researches are published as Bulletins, Technical Papers or Reports of Investigation. For more information on activities of BurMines, see "United States Government Organization Manual 1961-62", USGovtPtgOff, Washington 25, DC, Revised as of June 1961,pp 247-8 & 661

**Bureau of Naval Weapons**(BuWeap), US Navy, Washington 25, DC, formerly Bureau of Ordnance, is responsible for the research, development, design, testing, operating standards, manufacture, procurement, fitting-out, storage, distribution, issue, maintenance, alteration, repair, overhaul, material effectiveness, disposition and salvage of all naval weapons, ammunition, explosives, propellants, pyrotechnics, war chemicals, aircraft and other equipment. The Bureau is also charged with operation of weapons, expls & proplnts plants, laboratories, torpedo stations, ammo depots, ordnance test stations and other naval establishments. For a more complete description of its functions, see "United States Government Organization Manual 1961-62", USGovtPtgOff, Washington 25, DC, Revised as of June 1, 1961,p 178

**Bureau of Ordnance**(BuOrd), US Navy, established in 1842 and abolished in 1959. Its functions were transferred(with those of Bureau of Aeronautics) to the Bureau of Naval Weapons(qv), effective not later than July 1, 1960

**Bureau of Standards or National Bureau of Standards(NBS)**, Washington 25, DC. It was established in 1901 as a part of the Treasury Dept and was transferred in 1903 to the Dept of Commerce and Labor. The fundamental purpose of the Bureau is to provide national leadership in the development and use of accurate & uniform techniques of physical measurements. It conducts fundamental research in physics, chemistry,

mathematics and engineering in order to lay the ground work for new standards. It also tests, calibrates and certifies various measuring devices, such as thermometers, barometers, etc. The Bureau at present publishes: The Journal of the National Bureau of Standards and Technical News Bulletin. It formerly published: Bulletin of the Bureau of Standards(1904-1919), which was replaced by Scientific Papers(now discontinued). There were also published Technological Papers, which also have been discontinued. For more info on NBS see "United States Government Organization Manual 1961-62", USGovtPtgOff, Washington 25, DC, Revised as of June 1961,pp 309-11 & 668

**Burette Calibration.** See under Calibration of Laboratory Glassware

**Burn Cuts.** A term used in blasting operations. See Blaster's Hdb(1952), 260-2

**Burned Shots.** Same as Blown-out Shots(qv)

**Burner.** A device for obtaining a flame by the combustion of solids, liquids or gases. In rocketry, it means a fuel-injection nozzle in the combustion chamber of a jet engine or the combustion chamber itself
*Refs:* 1)Hackh's(1944), 144 2)DictGuidedMissles (1959), 104

**Burner Plate.** The term occasionally used by Brit rocket technologists for "injector"
*Ref:* RocketEncycl(1959), 60

**Burning and Combustion**(Definition). *Burning* in common usage is defined, in Ref 2, as a *combustion* is which material is consumed by fire resulting from interaction of the material with atmospheric oxygen at high temperature and accompanied by flame and sometimes sound

According to Ref 1, the term *combustion* implies the process of *burning* and in the popular mind is generally associated with the production of *flame*. So far as terrestial conditions are concerned, combustion is due to the combination of a combustible substance with oxygen and the consequent evolution of heat. The appearance of flame is due to the oxidation of gases or vapors at a very rapid rate so that high temps are obtained, the molecules involved thereby becoming very radiant. Scientifically, the term combustion has a broader meaning and is extended to other forms of oxidation. At atm temp oxidation of a combustible material generally occurs, if at all, only very slowly, and usually with little outward manifestation. When, however, the temp is raised, as for example by the application of some external source of heat, the process becomes greatly accelerated and, when the "ignition point" is reached, heat will be developed at a rate greater than that at which it can be dissipated and flame will ensue. Thus, when a lighted match is applied to coal gas issuing from a jet, the temp is raised to the ignition point of the gas. Flame then appears and is maintained at the jet. Similarly, when coal is heaped on a fire, its volatile constituents, liberated by heat, mix with surrounding air and after ignition give rise to flame; the residual coke consists largely of carbon which becomes incandescent and burns without flame

Combustion must be distinguished from *deflagration, explosion* and *detonation*(See also Combustion, Catalytic and Combustion, Spontaneous)
*Refs:* 1)EncyclBritannica 6(1952), 98 2) Merriam-Websters(1961), 300

**Burning Area, Required.** In rocket technology, it is the area of solid-propellant material that is made available for combustion to satisfy the performance requirements at a particular moment in the firing interval. One of the means of varying the burning area is the selection of the proper configuration of a proplnt grain
*Ref:* Rocket Encycl(1959), 384

**Burning and Burning Characteristics of Explosives, Including Experimental Procedures.** Although the literature on the subject of burning of expls is very conflicting, it is possible to draw the following general conclusions:
a)Small charges of explosives, including all low expls and many secondary HE's(such as TNT, dynamites and blasting gelatin) can be made to burn quietly if they are unconfined
b)Burning of secondary HE's(especially PETN, RDX, and HMX) can lead, often after long delay, to detonation, especially if large quantities of materials are involved or if they are under strong confinement
c)Primary expls, according to some investigators, such as Muraour(Ref 18) and Griffiths & Groocock (Ref 24), detonate instead of burn; but some other investigators, such as Belyaev & Belyaeva (Refs 10 & 13), claimed that primary expls, with the exception of LSt, can burn in air when they

are highly compressed in the form of cylinders

A comprehensive review by Andreev on burning of expls is being published in several numbers of Explosivstoffe(Ref 25)

Experimental procedures for detn of burning rates and other characteristics of expls are discussed in Refs 2,10,15,20,20a,22,23 & 25

This section was reviewed by Dr J.P. Picard

*Refs:* 1)C.E.Munroe & J.E.Tiffany, "Physical Testing of Explosives", BurMines Bulletin **346**, USGovtPtgOff, Washington, DC(1931), 30-1 [Detn of rate of burning of low expls, such as black powder(blasting) in the Bichel pressure gage after certain modifications were introduced by A.B.Coates & J.E.Crawshaw] 2)A.W.Baker, ExplosivesEngr **17**, 115-17(1939) & CA **33**, 566 (1939)(Apparatus for detn of burning rates of pellets of BkPdr consists of a steel tube closed at one end. A cannon crusher gage is placed in the closed section of the tube and a pellet of BkPdr is then placed next to the crusher gage. The cartridge is fired electrically and the length of the gage is then measured and the amount of crushing is compared with that caused by a standard powder. The length that the crusher is shortened is proportional to the force of the blow which, in turn, is proportional to the speed of burning of the powder) 3)H.Mouraour, RevGenSci **44**, 567-71(1933)(A resumé and elaboration of theories of burning and detonation of HE's and proplnts discussed in earlier papers of Muraour et al) 4)M.Patry, SS **32**, 148-51,175-9,199-205, 225-31,264-9, 295-300 & 335-40(1937); Ibid **33**, 6-10,33-7,65-9,92-6 & 156-9(1958)(Burning and Detonation of various expls, such as Azides, Fulminates, Cheddites, Dynamites, PETN, PA, RDX, Tetryl, TNT and Tricycloacetoneperoxide) 5)A.F.Belyaev, ActaPhysicochim **8**, 763-8(1938) (in English); ZhFizKhim **12**, 93-9(1938) & CA **33**, 8992(1939)(As most secondary HE's are appreciably volatile near their ignition temps, the evapn may absorb most of the energy liberated at the burning face. B.therefore believes that their burning takes place in the gas phase and that the penetration of burning from the gas phase into the condensed phase may lead to the immediate development of detonation. Since most proplnts are not volatile they burn without detonation. This therory does not hold for some primary expls- their burning goes to detonation although they are not volatile at the temp of burning) 6)A.F.Belyaev, ZhFizKhim **14**, 1009-25 (1940) & CA **35**, 4207(1941); ActaPhysicochim **14**, 523-46(1941) & CA **36**, 4339(1942)(Discussion on burning of nitroglycol) 7)A.F.Belyaev, DoklAkadN **28**, 714-17(1940)(in Engl) & CA **35**, 5317(1941)(A mathematical discussion showing that under certain conditions where orderly burning of expls in parallel layers is disturbed by violent boiling of molten expl at the surface, or by presence of pores which permit the flame to penetrate into the mass, stable burning is not possible and there may be transition from deflagration to detonation) 8)K.K.Andreev, DoklAkadN **29**, 469-73(1940) & CA **35**, 6456(1941) [Investigation of burning of secondary HE's under increasing pressure was conducted in heavy iron tubes sealed at the bottom and closed at the top by a lead or steel disc. The pressure in the tube was controlled by varying the thickness of the disc. When ignited, gelatinous expls(such as gelatin dynamites or blasting gelatin) burned without detonation, while pulverulent expls detonated when the increase in the rate of burning produced a critical pressure in the combustion front. For example, RDX & PETN detonated under the confinement of a lead disc 2.5mm thick which corresponded to 65kg/cm$^2$ pressure while TNT, PA or tetryl required confinement of a steel disc which corresponded to a pressure of 500-700kg/cm$^2$] 9)K.K.Andreev et al, KhimReferatZh **1940**, No 10/11,p 120 & CA **37**, 1872(1943)(Experiments of A. et al have shown that in general the rate of burning of expls tends to increase with decrease in the diam of the tube, or decrease in the density. For some expls, such as Nitroglycol, 62% Gelatin Dynamite or Blasting Gelatin, the diam of chge does not seem to influence the rate of burning) 10)A.F.Belyaev & A.E. Belyaeva, DoklAkadN **33**, 41-4(in Ger)(1941) & CA **37**, 2183(1943) [Pellets of MF compressed at 1750kg/cm$^2$ decompd without detonation at atm and lower pressures in reactions which were self-supporting("burning"). The rate of "burning" of MF at 760mm was found to be 1.5-2.0cm/sec, which is higher than that for secondary HE's (0.05 to 0.1cm/sec). When the pressure was decreased to 100mm, the rate decreased and flame became longer but weaker. At 8mm and 2 to 3min, no flame could be seen and the pellets seemed to melt. B & B came to the conclusion that the burning of MF pellets at atm pressure is a two-step process, consisting of: a)the distintergration of part of the substances with formation of very small particles and b)the complete decompn of these particles, close to

the surface of the pellet] 11)Ya.B.Zel'dovich, ZhEkspTeoretFiz **12**, 498-524(1942) & CA **37**, 4249(1943)(Discussion on stationary and non -stationary burning of expls and proplnts. This includes rate of burning and transition from burning to detonation) 12)K.K.Andreev, ZhFizKhim **20**, 467-92(1946) & CA **41**, 283-5 (1947)(Discussion on burning of various liq & solid expls at low pressures) 13)A.F.Belyaev & A.E.Belyaeva, DoklAkadN **52**, 503-9(1946)(in Engl & Rus); complete translation OTS: 60-41, 512: JPRS: 4080(1960) may be obtained from OTS/USDC; CA **41**, 4309-10(1947) [Highly compressed cylinders of some primary expls burn at the rates: 1.55cm/sec for MF at d 3.80: 0.65 for TATNB at d 1.70; 0.95 for Tricycloacetoneperoxide at d 1.22; 2.15 for DADNPh at d 1.45 and 1.50 for K picrate at d 1.83. LSt exploded instead of burning but its mixt with 60% of talcum burned at the rate of 14.5cm/sec and the mixt of MF 60 & talcum 40% burned at the rate of 0.55cm/sec. At low press(10-22mm Hg) the character of the burning varied with the expl except that TATNB still burned with a stable flame] 14)K.K.Andreev, DoklAkadN **53**, 233-6 (1946) & CA **41**, 6722(1947)(Influence of cubic density on the burning of expls) 15)H.Muraour & A.Michel-Lévy, MAF **21**, 263-70(1947) & CA **44**, 8659(1950)(Spectral study of the phenomena of burning and detonation of expls) 16)G.N. Abramovich & L.A.Vulis, DoklAkadN **55**, 107-10 (1947) & CA **41**, 6723(1947)(Mechanism of propagation of detonation and of burning in expls) 17)A.F.Belyaev & A.E.Belyaeva, DoklAkadN **56**, 491-4(1947) & CA **44**, 8109(1950) [The rate of burning of some primary expls under increased pressure obeys the same law as was applied by Andreev(Ref 8) to secondary expls. If v is the linear rate of burning, p- pressure and A & b constants, then v=A+bp] 18)H.Muraour, "Poudres et Explosifs" Presses Universitaires de France, Paris(1947), 20-2(M, in collaboration with J.Basset, verified that all high expls including blasting gelatin but excluding primary expls can burn without detonation when ignited by a flame whether in the open or in a closed vessel at pressures up to 10000kg/cm$^2$) 19)H.C.Grimshaw, "Slow Burning of Permitted Explosives as a Possible Cause of Hangfires or Delayed Explosions", Ministry of Fuel and Power, Safety in Mines Research Establishment, Research Rept No **34**, 3-29(1951)(Brit) 20)L.Médard, MP **33**, 329-30(1951) [Two tests are described. In the 1st test, known as *combustion en goutière* (burning in a trough), a sample of loose expl is placed and leveled to fill a horizontal semi -cylindrical trough, 10 or 20mm in diam and 2.0m long, made of sheet steel, 2-mm thick. The length of the trough was marked at 0,0.5,1.0,1.5 & 2.0m. After igniting the expl(at the end marked O) by a Bunsen burner(or candle or alcohol burner), the time required for the flame from the burning explosive to travel the distances 0.5, 1.0m. etc is detd and the average rate of burning in cm/sec is calcd. In the 2nd test, called *combustion en tas conique*(burning in a conical pile), a sample of loose expl(1kg) is placed on dry, hard ground(or on a cement floor) in the form of a cone with the smallest possible base. After measuring the diam of the base and the height of the cone, the expl is ignited at the base by means of a torch and the time required to consume the pile by burning is observed. These two tests are used in the Laboratoire de la Commission des Substances Explosives, France] 20a)A.M.Gurvich & Yu.Kh.Shuvalov, "Termodinamicheskiye Izsledovaniya Metodom Vzryva i Raschety Protsessov Goreniya" (Thermodynamic Investigation by the Explosion Method and Calculations of Burning Processes), IzdatelMoscovUniv(1955) 21)A.Douillet, MP **37**, 167-96(1955)(Exptl study of the laws of burning of BkPdrs at atm pressure and below) 22)K.K.Andreev, "Termicheskoye Razolzheniye i Goreniye Vzrychatykh Veshchestv"(Thermal Decomposition and Burning of Explosives), Gosenergoizdat, Moscow(1957)(a book in Russian) 22)F.P.Bowden et al, "Combustion and Explosion of Crystals", in 6th Symposium on Combustion, Reinhold, NY(1957),pp 609-12(9 refs) 23)N. Griffiths & J.M.Groocock,ARDE(Great Britian) Repts(MX)5/59 & (MX)6/59,March 1959,"Burning of Solid Explosives to Detonation. Development of Photographic Techniques" 23a)C.Campbell & G.Weingarten, PicArsnMonograph **M43**(1959),"A Thermoanalytical Study of the Ignition and Combustion Reactions of Black Powder" 24)N. Griffiths & J.M.Groocock, JCS **1960**, 4154-62 & Explosivst **1961**, 276 [Expls other than initiating compds usually burn when ignited, but burning of secondary HE's(such as PETN, RDX or HMX) can lead to detonation often after a long delay, particularly if large quantities of materials are involved or if they are confined. Some tests conducted by these investigators showed that narrow columns of heavily confined secondary HE's achieved detonation after a relatively gentle

thermal ignition] 25)K.K.Andreev, Explosivst **1960**,54-61,102-11,167-77,275-84; Ibid **1961**, 198-207, 233-40, 257-64; Ibid **1962**,35-9,47-52, 136-48,158-68,177-86,203-12(to be continued) (Thermal decomposition and burning of expls)

**Burning and Burning Characteristics of Propellants for Artillery Weapons and Small Arms.** When a charge of colloidal propellant consisting of a number of geometrically similar pieces(called *grains*) is brought in contact with an igniter system capable of heating nearly simultaneously the surfaces of all grains to at least 170°F, the propellant starts to burn and evolve hot gases. The heat of these gases brings successive layers of the grains to the temp of ignition and this maintains continuous burning. If a proplnt is carefully prepd to achieve homogeneity, there is no reason why it should burn preferentially in any particular direction. It is, therefore, safe to assume that the surface of each grain recedes parallel to itself as burning proceeds. This phenomenon of burning in parallel layers was first observed in 1839 and is now known in internal ballistics as *Piombert's Law*. Some confirmation that this law is obeyed(at least approx) in practice is obtained by firing proplnts in guns with barrels too short to permit complete burning of grains while the projectile is still in the bore. The pieces of unburnt proplnt are then thrown from the gun and are caught in water to arrest burning. If the recovered grains are generally found upon examination to be of the same shape as the original grains but smaller in size, it proves the validity of Piombert's Law

Piombert's Law does not hold if the grains are perforated, because here the stream of hot gases, passing through the channels, causes their surfaces(internal) to burn faster than the external surfaces of the same grains. The increase in rate of burning is observed for any surface of a grain if it is subjected to the action of a stream of hot gases moving with an appreciable relative velocity, parallel(or nearly parallel) to the surface. The effect of causing an increase in rate of burning due to the movement of hot gases along the surfaces or through the channels of the grains is known as *erosion of propellants or erosive burning*. This effect is more pronounced with cool proplnts(such as those contg NGu) and depends at any time on the density of the proplnt, the size of perforations and the relative velocity of hot gases moving parallel to the surfaces of grains

The conditions of burning propellnts in a closed vessel and in a gun are not the same

In a *closed vessel,* the gas produced on burning, streams out along the normals to the proplnt surface and, if the chge is not concentrated near one end of the vessel, the gas velocities parallel to the burning surfaces are negligible. This means that if a proplnt burning in a closed vessel is without perforations(such as cordite), there is no erosion of the grains, but if a proplnt is perforated(as in US single- and multiperforated grains) there is erosion in channels but not on the outside surfaces of grains

In burning of proplnts in a gun, there is movement of the gas stream from breech to muzzle parallel to the grains of proplnt with a relative velocity of some hundreds of feet per second. Although the distribution of gas velocity along the bore at a given time is not known accurately, it is usually assumed that this velocity is proportional to the distance from the breech. Generally, it may be assumed that the proplnt burning in a gun behaves at first as in a closed vessel and then shows a rate of burning greater than found in a closed vessel at the same pressure. Near the end of burning the erosion effect may decrease, since the gas velocity along the proplnt increases but slowly at this time, while the propint velocity rises rapidly; hence the relative velocity can therefore fall. Further, the very last stages of burning are marked by a decreasing burning surface. The resultants of these effects is obviously complex (Refs 4,24,25 & 33)(See also Burning, Erosive of Propellants)

Propellants intended for use in rifles or guns are required to possess the following characteristics:

a)The burning shall be rather slow in order not to produce an excessive pressure of gases in the bore on firing. At the same time, that pressure shall be sufficiently high to impart to the projectile the desired muzzle velocity. This pressure shall not drop below a certain level while the projectile travels toward the muzzle

b)Burning shall be such that no excessive erosion of metal bore is produced and that the ballistics shall be regular, ie, when different projectiles of the same shape, diameter, length and weight are fired by equal wts of proplnts, practically identical muzzle velocities shall be obtained

c)Burning of completely gelatinized proplnts shall be uniform from the surface and shall obey

(approx) Piombert's Law(see above)(Refs 1,4,24, 25 & 33)

The term burning characteristics might include burning rate, burning time, burning temperature and some other properties

*Burning rate*, also called *quickness* or *speed of combustion*(Verbrennungsgeschwindigkeit in Ger, Vitesse de combustion in Fr, Skorost' goreniya in Rus, Velocità della combustione in Ital and Rapidez de la combustión in Span), may be defined as the rate(in mm/sec, cm/sec or in/sec) at the surface of a proplnt grain recedes when it is consumed in a combustion chamber

The rate of burning is dependent on the following:

a)*Composition of propellant.* In a single-base proplnt, the higher the N content of the NC the faster-burning is the proplnt. In a double-base proplnt, the higher the content of NG or of DEGDN, the faster and hotter is the proplnt. NGu is added to reduce the temp and the rate of burning. Non-expl ingredients, such as volatile solvents (alcohol, ether, acetone), plasticizers & stabilizers(vaselin, sym-dialkylureas,DPhA, centralites, acardites), flash reducers($K_2SO_4$, KH tartrate) and coating agents(graphite), considerably reduce the rate of burning and energy of proplnts. The same applies in a smaller degree to the presence of moisture in proplnts. Colloidal proplnts contg an emulsion as a stabilizer are faster-burning than similar proplnts with a solid stabilizer(such as DPhA or centralite) distributed homogeneously in the proplnt. The rate also depends on particle size of the solid ingredients. This is of particular importance in proplnts contg large amts of solid ingredients, such as "cool" proplnts contg NGu or "composite" rocket proplnts

b)*Size and shape of grains and web thickness.* When a proplnt is ignited at const pressure it burns at a uniform rate of speed in parallel layers in a direction perpendicular to all exposed surfaces, provided the compn is uniform (Piombert's Law). The greater the surface exposed to combustion, the faster is the proplnt, provided other factors, such as compn and confinement are the same in all tests. The finer granulated(smaller grains) proplnts possess greater surface per unit charge(or volume) and therefore burn faster then proplnts with coarser granulation(larger grains). The surface of large grains may be increased by flattening them

All solid grains, such as strips, cords, cubes, etc burn *degressively* because the surface area of the grain is reduced as the grain is consumed

All perforated grains, especially multiperforated ones, burn *progressively* because the burning surface of the grain increases as the grain is consumed

As to the *web thickness*, the larger the value, the slower is the proplnt. For single -perforated grains, as most US small arms proplnts are, the web thickness is equal to half the difference betw the outside diam(such as 0.049") and the diam of the perforation(such as 0.015")

c)*Porosity and surface treatment of propellants.* Porous grains(usually produced by insufficient gelatinization of NC) are faster burning than non-porous grains. Surface treatment of proplnts, such as with retardants or with graphite,produces proplnts which burn slowly at the beginning and faster after the upper layer has burnt out

d)*Pressure of confinement.* The higher the pressure the higher is the rate of burning of the proplnt provided other conditions are equal. When a proplnt starts to burn in a gun the pressure is atmospheric and the rate of burning is comparatively low. Then the pressure begins to increase due to evolving gases because the movement of the projectile toward the muzzle is not sufficiently fast to allow release of all the evolving gases. The increase of pressure in the bore causes the proplnt to burn faster than earlier and this causes a still higher rate of increase in pressure. The pressure and the rate of burning continue to increase until certain maximums are reached for both of them. The pressure then starts to decrease and this causes a decrease in the rate of burning. As soon as all the proplnt is consumed the projectile is ejected from the bore.

If a NC proplnt is "fast-burning"(for example, when NC is not sufficiently gelatinized or if the grains of proplnt are too small), the rapid combustion of part of the proplnt might create such a high pressure that the remaining chge would deflagrate or even explode(Ref 35). In NC-NG proplnts expln might take place if the content of NG is too high

According to investigations conducted by Brunswig(Ref 6), the effect of pressure on the rate of burning NC proplnts is not the same as for NC-NG proplnts. On plotting the pressures as abscissa and the rates of burning as ordinate, Brunswig obtained curves which showed the following: a)The rates of NC proplnts at low

pressures were always very low b)As the pressure increased to the middle range, the proportional in crease in rate for NC proplnts was slightly higher than for NC-NG proplnts c)When the pressure began to increase to higher range, the proportional increase became nearly equal for all proplnts and the curves became practically parallel to each other with the NC-NG curves considerably above the NC curves. In all cases the higher the NG content the higher was the final value for the rate of burning(see also Ref 13)

Burning rates can be detd experimentally(see Burning Characteristics of Propellants, Experimental Procedures) or they can be calcd approx by one of the equations listed below

Early gun ballisticians who burned proplnts at pressures of the order of 30000 to 50000 psi were satisfied to express pressure effects of burning artillery propellants by the equation: $v=bp$, where v is the rate of burning at a given temp, p- pressure and b a constant

According to Marshall 1(Ref 1), Vieille proposed in 1884, in collaboration with Sarrau, the following experimental equation: $v=cp^x$(Eq 1), where c & x are constants

As these equations did not hold for Brit Cordite, Mansell & Petavel proposed the following linear equation: $v=a_o+ ap$(Eq 2), where p is pressure, $a_o$ is the rate of burning at atm pressure and a is acceleration of the rate of burning per unit pressure. After a certain pressure has been produced, the value a increases rapidly to become constant until all of the proplnt has been consumed. This constant, known as *burning velocity index* is of major importance in the burning of artillery proplnts (Ref 29a,pp 229-30)

Eq 2 is written in Ref 29a as: $R=a + bp$

Eq 1, known as Vieille's Law or "exponential formula", is used now by many investigators(especially in rocketry),while Eq 2 has been preferred by Muraour and his school

The present accumulated data for various types of colloidal proplnts permits one to det approximately their rate of burning if composition and/or some properties(such as calorimetric value or temp of expln) are known. This knowledge, is purely empirical and does not explain the process of burning as would a good *theory of burning*. The real value of a theory lies in its physical and chemical picture of the process. If a theory is close to the truth it helps one to understand not only the burning itself but also the various phenomena associated with burning of proplnts, such as erosion of proplnts, ignition, erosion of the gun barrel, etc. A successful theory would provide a general understanding of these phenomena and might indicate the possibilities of control. Although a theory of burning may show small discrepancies from experimental data, it is, however, useful

All theories of burning described up to the present in open literature may be divided into surface theories and vapor-phase theories

A)*Surface theories*. According to these theories burning is controlled by the rate at which energy (such as heat) is transmitted from the hot gaseous products to the surface of solid proplnts (Ref 24,pp 43-7 and Ref 25,pp 24-5). These theories have been suggested by Létang(Ref 2), Schweikert(Ref 3), Muraour(Refs 5,7,8,9 & 11), Yamaga(Ref 10) and Crow & Grimshaw(Ref 12). A review of Muraour's work was given by Schmidt(Ref 15). All surface theories lead to the conclusion that the rate of burning depends upon the gas temp near the solid and that the rate is proportional to pressure(except at high pressures where the effect of the finite size of the gas molecules becomes significant)(Ref 24,p 47)

B)*Vapor-phase theories*. According to these theories the reaction of burning procedes in the layer of gas just outside of the solid(Ref 24,pp 47-9 and Ref 25,p 25-6). These theories have been suggested by Boys & Corner(Refs 22 & 23), Belyaev(Ref 18) and some other investigators

Saenger(Ref 26) proposed a hypothesis which considers the process of burning of a solid proplnt to occur in three layers. In the 1st layer, a partial decompn takes place betw the starting temp $T_1$ and the ignition themp $T_2$. In the 2nd layer(separation layer) the proplnt molecules melt, boil and vaporize and in the 3rd layer(reaction layer) the substance burns to $CO_2$ & $H_2O$ at temp $T_3$. By considering that the heat absorbed betw $T_1$ & $T_2$ and betw $T_2$ & $T_3$ is converted to chemiluminescene of the combustion gases, a formula is developed for the stationary rate of burning of the proplnt. For more info on the subject consult the original paper

The same investigator(Ref 26a) gave for burning of NC-NG proplnt the following expression: $V=I/\gamma(E_{12}+ E_{23})$ where I is the intensity of radiation produced, $\gamma$ - density, $E_{12}$ - heat evolved in going from ambient temp to flash temp,and $E_{23}$- heat evolved in going from flash temp to combustion temp

Increase in the initial temp of a proplnt

causes an increase in the burning rate. Decrease in burning rate because of decrease in initial temp results in decreased pressures; and because of difficulty in achieving satisfactory ignition, there frequently results an increase in the variation of projectile velocity. The effects in changes in the initial temp is less pronounced in artillery ammo than in rockets(Ref 29a,p 231)

Burning characteristics of std US gun, proplnts at temps 21° to -52°C is discussed by Shulman et al(Ref 36)

A brief mathematical discussion of effect of temp on burning rate is given under Burning and Burning Characteristics of Propellants for Rockets

This section was reviewed by Dr. J.P. Picard

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**Burning and Burning Characteristics of Propellants, Experimental Procedures.** The simplest method for experimental detn of burning rate is to measure the time required for a long strand(or stick) of proplnt to burn in a closed vessel

either in air or in an inert gas(such as nitrogen) at a desired pressure and temperature. Electronic timing apparatus(Refs 1,2,3,4,5 & 7) or other devices(Ref 10) may be used for measuring the time of burning. A description of Crawford-type strand-burning apparatus suitable for testing all types of solid proplnts is given in Ref 15,p 91. A closed bomb type apparatus for measuring rates at const pressure is described in Ref 16. Devices permitting one to interrupt the burning of a proplnt at any preselected time and to quench it are described in Ref 12 and in Ref 15,pp 177. This method permits examination of partially burned proplnt grains

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**Burning and Burning Characteristics of Propellants for Rockets.** "Burning" in rocket technology refers to the interaction of oxygen molecules of a gaseous, liquid or solid oxidizer with fuel molecules, resulting in a chain of extremely complex reactions that take place when the molecules rearrange to yield oxides, water, gaseous elements and/or small amts of other molecular species(Ref 29)

Two kinds of proplnts are used in rockets: *solid* and *liquid*. Solid rocket proplnts can be either colloidal double-base or composite proplnts, while liquid proplnts can be either mono- or bipropellants

The burning of *double-base* rocket proplnts proceeds in parallel rows in a manner similar to the burning of proplnts described under "Burning

and Burning Characteristics of Propellants for Artillery Weapons and Small Arms", where several theories of burning are mentioned. To these may be added the theory developed in 1950 by Crawford et al(Ref 10). They consider the burning of double-base proplnts as occuring physically in three distinct zones identified as the foam, the fizz and the flame zones. Since burning takes place in parallel layers, it can be considered as one-dimensional and which progresses in a direction perpendicular to the surface of the proplnt and which passes through each zone sequentially. This process is described more fully by Warren(Ref 25,pp 98-100)

The burning of *composite* rocket proplnts is more complicated because they contain many ingredients. Several oxidizers and many fuel binders are used to formulate composite compns. The burning of this class of comparatively recent proplnts has not been as well explored as the older NC-NG-base proplnts. Both Geckler(Ref 21a) and Huggett(Ref 24,p 565) present a good review of the burning mechanism as it is understood today(see also Ref 25,pp 100-1)

The *liquid* rocket proplnts are introduced into the combustion chamber of a rocket through an injector in the form of droplets. The droplets then vaporize at their surface and the vapors start to burn. The mechanism of burning differs, however, depending upon whether the proplnt is a monopropellant or bipropellant, and, if a bipropellant, whether it is *hypergolic* or *nonhypergolic*

In the *monopropellant* system each droplet is like every other and the vapors produced are the same in composition(consisting of a fuel and an oxidizer). When these vapors are heated to their ignition point(by means of a special igniter), they burn without any air being introduced from outside

In the *bipropellant* system two liquids, one a fuel and the other an oxidizer, are introduced through separate injector nozzles into the combustion chamber to form droplets of each material. Mixing of droplets(or of their vapors) produces a combustible material which in *nonhypergolic* systems is ignited in a manner similar to monopropellant systems. When *hypergolic* systems are used, the burning of the vapors begins spontaneously upon mixing of two substances and no igniter is required. For optimum performance with bipropellants, it is necessary that the fuel and oxidizer be fed in a ratio which will produce complete combustion, and hence maximum energy release. This is known as the *stoichiometric ratio*(Ref 25,pp 88-107)

If the process of burning of any rocket proplnt(except those contg inorganic ingredients) is considered to go to stoichiometric completion, the end products would be $CO_2$, CO, nitrogen and water. However, because of extreme temps developed by the gases during burning, considerable dissociation and other reactions can take place giving products such as hydrogen, solid carbon, oxides of nitrogen, ammonia, hydrocarbons, etc. Under the conditions normally encountered in rocket combustion chambers, it is considered that the time required for the passage of the gas from the reacting surface to the exhaust nozzle is sufficient to allow reasonable approach to chemical equilibrium(see also Ref 10,p 3)

The rate of burning of a solid double-base proplnt at a given initial temp can be calcd by the same formula as given under "Burning and Burning Characteristics of Propellant for Artillery Weapons and Small Arms". However, according to Warren (Ref 25,pp 92-3), when rocket proplnts were being developed during WWII, the exponential formula (Eq 2) was selected on the basis that proplnts such as JPN followed this relationship very well

JPN is a solventless extruded proplnt which was used extensively during WWII for propelling rockets. Its compn was: NC(13.25%N) 51.5, NG 43.0, DEtPh 3.25, EtCentr 1.0 and $K_2SO_4$ 1.25% with added carbon black 0.2 and candellilla wax 0.08%(Ref 25,pp 5 & 9)

The exponential formula is given in Ref 25,p 92 as:

$$r=BP^n$$

where r is the linear burning rate expressed in in/sec, P is pressure in psi developed in the combustion chamber of a rocket and B and n are empirical constants characteristic of the proplnt at a given temp(see also Refs 29 & 30)

Solid rocket proplnts, being required to function under steady-state pressure conditions much lower than the max pressure under which artillery proplnts burn, have max burning rates correspondingly lower than those of artillery proplnts(Ref 21a)

Wimpress(Ref 11,p 17) prefers to write the exponential equation as follows:

$$B=\beta(p'/1000)^n$$

where B is the linear rate of burning in in/sec, $p'$ - pressure in the combustion chamber in psi, $\beta$ - a constant at a given temp which represents the linear burning rate of the proplnt at 1000psi and n is a measure of the sensitvity of the burning to changes in the pressure. The term($p'/1000$) is

used instead of the pressure directly merely because it simplifies numerical calcns and aids somewhat in comparison of the characteristics of different types of proplnts

In general, homogeneous proplnts, such as double-base colloidal proplnts, have a value of n in the range 0.6 to 0.8,whereas heterogeneous proplnts, such as BkPdr or composite proplnts, have a lower value. The effect of the temp on burning rate is primarily reflected by a change in the coeff $\beta$. Temperature in many cases also effects the exponent n; but for pressures at which rocket motors normally operate, the changes in n may be considered negligble

Following are average burning-rate constants for typical rocket proplnts

| Propellant | n | $\beta$, in in/sec at: 0°F | 70°F | 140°F |
|---|---|---|---|---|
| JP | 0.71 | 0.551 | 0.671 | 0.815 |
| JPN | 0.61 | 0.564 | 0.651 | 0.752 |
| Russian Cordite | 0.70 | 0.250 | 0.290 | 0.337 |

Compn of *JPN* is given above. *JP* contained NC(13.25%N) 52.2, NG 43.0, DEtPh 3.0, DPhA 0.6 & $KNO_3$ 1.2% with added nigrosine dye 0.1%; *Russian Cordite* contained NC(12.2%N) 56.5, NG 28.0, DNT 11.0 & EtCentr 4.5% with added candelilla wax 0.08%

Based on the calcd values of $\beta$'s, the proplnts JP and JPN may be considered as "fast-burning", while Russian Cordite is "slow-burning"

The influence of composition on burning rates of propellants is discussed by Warren(Ref 25,pp 96-7)

A mathematical discussion on influence of temp on burning rates of proplnts is given in Ref 10,pp 18 & 83-4 and in Ref 25,pp 93-4. The formula given in Ref 25 is that of A.D.Crow & W.E.Grimshaw, PhilTrRoySoc **203A**, 387(1932), which is as follows:

$$r=\frac{B^1 p^{n^1}}{T_o - T}$$

where $T_o$ is a constant which is dependent upon the compn of the proplnt and has dimensions of temperature. The pressure exponent n is usually an average of the individual slopes of the rate-pressure(log-log) curves for each temp. $B^1$ and $T_o$ are obtained from the experimental data by plotting 1/r against temp in the chamber T and determining the slope and intercept of the resulting straight line. The constant $T_o$ has some theoretical significance since it represents the temp at which burning would take place instantaneously. Hence, this should be the surface temp. Values for $T_o$, calcd from data obtained on some experimental double-base compns tested in small rockets motors,ranged from 165° to 369°F. The ignition temp of double-base proplnts is believed to be ca 400°F(Ref 25,p 94)

Burning characteristics of some solventless -extruded double-base proplnts at a given pressure and initial temp are appreciably faster near the center of the web(ie toward the end of burning) than at the surface of the grain. This increase is probably due, at least partly, to heating of the grain by energy radiated from the burning gases and to a lesser degree from heating of the motor wall with correspondingly greater radiation of energy back to the burning surface(Ref 10,pp 18-20). This increase in burning rate should not be confused with that caused by erosion(see Burning Erosive of Propellants)

When some solid proplnt grains, particularly those with relatively long circular channels available for gas flow, are fired in rockets, there are frequently observed certain periodic pressure oscillations. These resonating pressures sometimes reach amplitudes high enough to cause the grain to crack and, in some cases, ultimately to rupture the rocket chamber. The average burning rate for the proplnt during these oscillations is always higher than expected. This phenomenon of unstable burning is known as *resonance burning* [See under Burning, Unstable (in Rocket Motors)]

Experimental procedures for detn of burning rates of rocket proplnts are practically identical with those described under "Burning and Burning Characteristics of Propellants for Artillery Weapons and Small Arms". The method described by Warren(Ref 25,pp 90-1) uses a modified Crawshaw strand-burning apparatus. This method is used with solid strands ca 1/8" in diam and 7" long and which are coated with a plastic so that they burn from one end only

Other methods are given in Refs 2 & 3

This section was reviewed by Dr J.P.Picard

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*Note:* Equation $\log V = 1.37 + 0.27T/1000$, discussed in the above papers, was changed by H.Muraour & G.Aunis, CR **225**, 381-3(1947) & CA **42**, 2431 (1948), to $\log V = 0.13 + 0.54T_{B1}/1000$ where V is diminution(in mm per sec) in thickness of grains of proplnt and $T_{B1}$ = temp reached after NO has completely disappeared] AA)H.Muraour et al, MAF **22**, 517-93(1948) & CA **44**, 8659(1950)(Detn in bombs of "vivacity" of burning of colloidal proplnts by using the expression $K_1 ET/\int pdt$) BB) H.Muraour & G.Aunis, MAF **23**, 859-66(1949) (Study of burning characteristics of colloidal proplnts of different compns, forms and sizes) CC)H.Muraour & G.Aunis, CR **228**, 818-20(1949) & CA **43**, 5189(1949)(Study of the laws of burning of colloidal proplnts at pressures 50 to 100$kg/cm^2$) DD)R.E.Gibson, Edit of "Symposium on Kinetics of Propellants", JPhChemColl **54**, 850-53(1950) (Elementary ideas concerning the burning of solid proplnts) EE)B.L.Crawford, Jr et al, Ibid **54**, 854-62(1950)(Mechanism of burning of double-base proplnts) FF)Jacques & James Basset, CR **231**, 649-51(1950) & CA **45**, 1769(1951) [Investigation of burning rates of five double-base proplnts and one chlorate proplnt subjected to pressures up to 10000 $kg/cm^2$ showed that the linear equation betw the rate and pressure developed by Muraour and discussed in CR **187**, 289(1928) & CA **22**, 3992(1928) does not hold even at pressures of 1000 $kg/cm^2$ or less] GG)H. Muraour & J.Fauveau, Chim & Ind(Paris) **65**, 53-5 (1951) & CA **45**, 7353(1951)[The laws of burning of colloidal proplnts in nitrogen at pressures from 100 to 10000 $kg/cm^2$. Remarks on the paper of J. & J. Basset(see previous ref)] HH)J.D.Huffington,

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**Burning and Burning Characteristics of Pyrotechnic Compositions.** This subject might include data on burning rate(or time), luminous intensity(in candles), heat of combustion and some other props. Some work on this subject has been done in the US, such as at PicArsn, Dover, NJ (Refs 2,13,16,17,18,20 & 23) and at NavalOrdLab (Refs 8,9,10 & 21). Some Brit data are given in Refs 4 & 12 and some French data in Ref 5. See also Refs 11 & 24

*Shidlovskii*(Ref 15) discusses the theory of burning pyro compns and gives formula for detg their rates of burning. He lists the linear rates of burning in mm/sec for the following stoichiometric binary pyrotechnic compns when compressed to densities 0.7-0.9: S + $KClO_3$ 2, S + $Ba(ClO_3)_2$ 2, charcoal + $KClO_3$ 6, charcoal + $Ba(ClO_3)_2$ 2.5, charcoal + $KNO_3$ 2, charcoal + $NaNO_3$ 1, charcoal + $Ba(NO_3)_2$ 0.3, sugar + $KClO_3$ 2.5, sugar + $Ba(ClO_3)_2$ 1.5, sugar + $KNO_3$ 1, sugar + $NaNO_3$ 0.5, sugar + $Ba(NO_3)_2$ 0.1, shellac + $KClO_3$ 1, shellac + $Ba(ClO_3)_2$ 1, shellac + $KNO_3$ 1, shellac + $NaNO_3$ 1 and shellac + $Ba(NO_3)_2$ 0.8

He also gives: for illuminating mixts 1-10mm/sec, tracing mixts 2-10, signal lights 1-3, incendiary(thermites) 1-3 and smoke mixts 0.5-2mm/sec

The higher the mixt is compressed, the slower it usually burns. For example, a pyro mixt (compn not given) compressed at 1000kg/cm² had a burning rate of 5mm/sec; compressed at 2000kg/cm² 4.2, at 3000 3.8 and at 4000 3.6mm/sec. It seems that compression above 3000kg/cm² has no effect on the rate of burning

This section was reviewed by Mr. G. Weingarten

*Refs:* 1)A.Stettbacher, Nitrocellulose **13**, 203-7 & 224-9(1942); CA **37**, 5240(1943)(The heat and light development of incendiary and flare compns) 2)D.Hart & H.J.Eppig, PATR **1669**(1947)(Burning

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**Burning Characteristics and Thermal Decomposition Products of some Synthetic Cellular Materials.** The use of synthetic cellular materials in various applications may lead to potential hazards from toxic, gaseous decomposition products if these materials are subjected to high temps or if they are burned from accidental causes

In the production of certain expanded plastic materials, chemical blowing(foaming) agents are frequently used to produce a cellular structure. One of these agents, *azo-bis-isobutyronitrile*, designated PN, decomp by heat with release of nitrogen and formation of toxic tetramethyl-succino-nitrile(designated TSN), according to the following reaction:

$$NC.C(CH_3)_2.N{:}N.C(CH_3)_2.CN \xrightarrow{Heat} N_2 + NC.C(CH_3)_2.C(CH_3)_2.CN$$

The problem of toxicity was investigated at the USBurMines with regard to cellular materials

polyvinylchloride & acrylonitrile and of foaming agents such as the PN mentioned above
*Ref:* H.A.Watson et al, BurMines Rept of Investigation RI **4777**, Pittsburgh, Pa(1951)

**Burning, Degressive.** See Burning Regressive

**Burning, Erosive(in Guns).** See Erosion in Guns

**Burning, Erosive(in Propellants)**(Erosive Effect of Gas Flow or Erosion of Propellants). Mansell (Ref 1) was one of the first to observe that the rate of burning inside tubular proplnts was faster than that on the outside. A similar phenomenon was observed later by Muraour(Ref 2). No importance was attached to this phenomenon until it was observed also(but on a larger scale) in rocket motors during and after WWII(Ref 11)

Investigations of burning of solid rocket proplnts have shown that higher than usual rates of burning of some grains surfaces is due to high velocities of hot gases flowing over these surfaces. This *erosive effect of gas flow* is probably attributable to improved heat transfer from the gas to the solid phase as a result of its high velocity. Erosive action takes place in regions where combustion passages do not have sufficient cross-sectional area for the hot gases to flow out toward the nozzle at a low velocity. The front and nozzle ends of the partly burned grain usually show the effects of erosive burning. In these instances the final web thickness at the nozzle end, where high gas velocities are encountered, is appreciably smaller than at the front end, where the gas velocities are lower

Several theories have been proposed for explanation of the erosive effect of gas flow in proplnts(See Refs 4,5,7 & 13)

The effects of high gas velocity upon linear burning rate can be expressed in terms of an *erosion coefficient*. Two different methods for its calcn are given in Ref 13

The effect on the linear burning rate that is related to the velocity at which hot combustion gas flows over the burning surfaces is known as the *erosive-burning effect*(Ref 13)

For more info on erosion of proplnts see the Refs listed
*Refs:* 1)J.H.Mansell, PhilTrRoySoc **207A**, 243 (1907) 2)H.Muraour, BullFr **41**, 1451-61(1927) 3)R.J.Thompson & F.T.McClure, OSRD Rept **5831**(1945)(Erosive burning of double-base proplnts) 4)J.Corner, TrFarafSoc **43**, 635-42(1947) 5) Corner, Ballistics(1950), 74-6 6)Wimpress, Ballistics(1950), 22-5 & 65-6 7)SACMS, Ballistics (1951), 38-9 8)L.Green, Jr, JARS(JetPropn) **24**, 9-21 & 26(1954)(Erosive burning of some composite explns) 9)P.Tavernier et al, MP **37**, 207-15(1955) (Study of erosive burning of colloidal proplnts) 10)J.Boisson,MP **30**,381-96(1957)(Erosive burning of colloidal proplnts) 11)P.Tavernier & J. Boisson, Chim & Ind(Paris) **78**,487-93(1957) (Erosive burning of colloidal proplnts) 12)J.M. Lenoir & G.Robillard,"A Mathematical Method to Predict the Effect of Erosive Burning in Solid -Propellant Rockets" in 6th Symposium on Combustion, Reinhold,NY(1957),663-7 & CA **52**, 4953-5(1958) 13)RocketEncycl(1959),148-9 14) DictGuided Missiles(1959),105

**Burning Fuse or Running Fuse.** Same as Safety Fuse(see under Fuses)
*Ref:* Marshall **2**(1917), 536, footnote 1

**Burning Ground or Destruction Site.** A tract of land designated for destruction of ammo, expls or proplnts by burning. The ground(preferably located on otherwise useless lands, such as with gullies or other defects ), should be located at the maximum practicable distance from operating or inhabited bldgs, magazines, railroads or highways. The minimum distance must be 2400ft unless pits or other obstructions are used to limit the range of fragments. In this case the appropriate "missile distance" will apply(Ref 5, secn 17-6 and tables). The area should be cleared within a radius of 200ft from the point of burning, of dry grass, leaves, dry bushes, and other combustible extraneous materials to prevent the fire from spreading. The ground around the point of burning should be well-packed earth, free from large stones and deep cracks. Fire-fighting facilities should be available to extinguish any undesirable fires and, if necessary, to "wet down" the ground betw burnings and the closing of each day of operation. Ordinary combustible rubbish should be burned separately from expls or ammo at a different location. When destroying expls or ammo by burning, the possibility of the mass detonating should be recognized and appropriate protective barriers or distance separation utilized for the protection of personnel and property

Trucks transporting expl materials to burning grounds should meet the requirements of Ref 5, secn 22. The expl material transported should be covered with a tarpaulin and no more than two persons should ride in the cab. While the material is being unloaded at the burning ground the motor

of the truck should be stopped and as soon as the unloading is completed the expl or ammo should be covered with a tarpaulin before the motor of the truck is started and the truck driven away. After distributing expl materials to points where destruction is to take place(no more than a one-day supply is allowed) the truck should be withdrawn from the area to a safe location and remain there until destruction is completed

Material awaiting destruction should be stored at not less than the "intraline" distance (see Note below and Ref 5, secn 17-4) from adjacent stores of expl materials. The material should be protected against accidental ignition or expln from fragments, grass fires, burning embers, or the detonating impulse originating in materials being destroyed

*Note: Intraline distance* is the minimum permitted betw any two bldgs within one operating line or, in some cases, betw bldgs, areas or locations even though actual line operations are not involved. Intraline distance is expected to protect bldgs, etc from propagation of expln due to blast effects but not against the possibility of propagation due to missiles

The burning of expls or ammo is conducted as briefly outlined in the item entitled "Burning of Ammunition and Explosives for Destruction". See also under individual items, such as Black Powder, Bombs

*Refs:* 1)M.Kostevitch, "Burning Ground", Imp d'Art Voltaire, 34 rue Richer, Paris(1927) 2)US Army, Chief of Ordnance, "Safety and Storage Manual", OO Form No **5994**, Washington, DC(1928), secn XI,pp 3-4 3)Anon, "Ammunition Inspection Guide", War Dept Tech Manual, TM **9-1904**, Washington, DC(1944), 772-7 4)R.D. Leitch & P.R.Moyer, Bureau of Mines Information Circular IC **7335**(1945) 5)Anon, "Ordnance Safety Manual", ORD **7-224**, Washington, DC (1957),secns 17,22 & 27 6)B.Kanouse & C.V. Ruskewicz, PicArsn, Dover, NJ; private communication(1961)

**Burning, Neutral.** In general, it is the burning of a solid proplnt of such granulation that its surface area remains constant during burning(Refs 1 & 2)

In rocketry, the term might mean the consumption of a solid proplnt chge in a rocket thrust chamber in a manner that results in the gas pressure remaining constant

*Refs:* 1)Ohart(1946), 23 2)Glossary of Ord(1959), 194 3)RocketEncycl(1959)-not found

**Burning of Ammunition and Explosives for Destruction.** This is one of the methods used for the destruction of expl materials which cannot be economically salvaged

Following are the types of expl material which can be destroyed by burning: black powder(qv), smokeless proplnts, TNT, PA, Tetryl, Expl D, pyrotechnic items, small arms ammo, primers, fuzes, detonators, boosters, fragmentation grenades and some chemical ammo

The operation should be conducted in a specially selected area, called "Burning Ground"(qv), also known as Destruction Site

Except in special cases, such as projectiles loaded with Expl D, ammo and expls should not be burned in containers nor should expls be burned in large lumps because of danger of detonation

Bulk initiating expls should be destroyed by detonation except that small quantities(not more than 28g) can be decomposed chemically. Loose, dry expls(other than initiating expls) or proplnts can be burned in beds not more than 3" deep. Ignition is accomplished either by means of a safety fuse of such length as to permit personnel to reach a protection shelter or by a black powder squib initiated by an electric current controlled from a distance or from a structure which assures safety to personnel. Wet expls and ammo require a thick bed of readily combustible material, such as excelsior, underneath and beyond to assure that all the expls & ammo will be consumed once the combustible materials are ignited. RDX is usually burned wet to prevent detonation. In all cases the materials should be so arranged that combustion proceeds in the direction opposite to that from which the wind is blowing

When misfires occur, personnel should not return to the point of initiation for at least 30 mins, after which not more than 2 qualified persons should be permitted to examine the misfire

Volatile flammable liquids should not be poured over the expls, ammo or underlying combustible materials to accelerate burning, either before or while the materials are burning

Explosive dusts and scrap pyrotechnic materials previously collected into receptacles partly filled with mineral oil No 10(as described in Ref 3, secn 27, paragraph 2705) are burned by emptying the receptacles into a shallow metal pan and igniting as described above(see also Ref 4)

When the burning ground becomes unduly contaminated(as decided by qualified personnel) it must be decontaminated by thoroughly soaking it with water and leaving it to dry. Detailed

description of various methods of decontamination may be found in SD(Supply Bulletin) **5-52**, 11 July 1945

Parallel beds of expls prepd for burning should be separated by not less than 150ft. In repeating burning operations, care must be taken not to allow any smoldering or hot objects to be left on the ground from previous burning. Burning should not be repeated on previously burned-over areas within 24 hours unless the area is first soaked with water and then inspected by competent personnel

Some types of expls and tracers or igniter compns give off toxic fumes when destroyed by burning. Proper respiratory protective equipment, such as hose masks, airline masks, and self -contained breathing apparatus should be worn where such fumes are likely to be encountered

Fire-fighting facilities must always be ready to fight grass or bush fires, but when exceptionally large amts of expls have to be burned, the local fire dept should be notified (See also Burning Ground and under individual items, such as Black Powder, Bombs, etc)
*Refs:*1)US Office Cheif of Ordnance, "Safety and Storage Manual", OO Form No **5994**, Washington, DC, secn XI(1928) 2)Anon, "Ammunition Inspection Guide", War Dept Tech Manual, TM **9-1904**(1944), 772-7 3)Anon, "Ordnance Safety Manual", ORD **7-224**, Washington, DC(1951), secn 27-13 to 27-15 4)Anon, "Military Pyrotechnics, TM **9-1370-200**(1958), 127-8 5)B. Kanouse & C.V.Ruskewicz, PicArsn, Dover, NJ; Private communication(1962)

**Burning of Black Powder; Inhibition by Foreign Substances** is discussed by S.Bentur et al, PrRoySoc **230A**, 33-46(1955) & CA **49**, 1539-40 (1955)

**Burning of Explosives.** See Burning and Burning Characteristics of Explosives

**Burning of Propellants.** See Burning and Burning Characteristics of Propellants

**Burning of Various Substances.** Following are some refs on this subject: 1)P.G.Demidov, "Osnovy Goreniya Veshchestv," Gosizdat, Moscow (1951) 2)R.Steinberger, "Mechanism of Burning of Nitrate Esters", in "5th Symposium on Combustion", Reinhold, NY(1955), 205-11 3)C.J.Malm et al, IEC **47**, 2521-3(1955) & CA **50**, 4507-8(1956) (Burning behavior of some cellulose ester film compositions such as cellulose acetate)

**Burning-out of Lyddite and other Shells** as conducted after WWI in Europe is described by M.M. Kostevitch in a pamphlet entitled "Methods for the Safeburning-out Lyddite and other Shells" Talleres Gráficos, Buenos Aires(1944)

**Burning, Physical Law of(in Interior Ballistics).** M.Serebryakov published a book in 1940 on this subject, in Russian. An abbreviated English translation of the book was made by V.A. Nekrassoff for the Catholic University of America, Washington 17, DC, under Navy Contract NOrd **10260**, April 1, 1955

**Burning, Progressive.** In general, it is the burning of a solid proplnt of such granulation that its surface area gradually increases during burning (Refs 1 & 2)

In rocketry, the term means the consumption of solid proplnt chge in a rocket thrust chamber in a manner that results in a gradually increase of pressure(Ref 3)
*Refs:* 1)Ohart(1946), 23 2)Glossary of Ord (1959), 223 3)RocketEncycl(1959), 64

**Burning Rate.** In general, this is the rate of consumption per unit time by burning a combustible material(such as a gas, liquid or solid). It can be expressed in grams, kilograms, pounds, etc per second, minute, hour, etc; milliters, liters, cubic meters, gallons, etc per second, minute, hour, etc; or in millimeters, centimeters, inches, etc per second, minute, hour, etc(see also Burning Rate, Linear)

**Burning Rate Coefficient**, sometimes designated as **Burning Rate Constant.** It is the interior ballistics parameter "a" in the solid-propellant linear burning rate formula: $r = ap^n$, where r is linear burning rate, in/sec; p- pressure, psi and "n" the *burning rate exponent.* Formulae for calcns of "a" and "n" are given in Ref
*Ref:* Rocket Encycl(1959), 61-2

**Burning Rate Constant.** Same as Burning Rate Coefficient

**Burning Rate Exponent.** See under Burning Rate Coefficient

**Burning Rate Linear.** This is the distance normal to any burning surface of a solid substance(such

as a propellant) consumed by burning in unit time. In a rocket proplnt, the linear burning rate can be best explained by considering an *end-burning grain*, properly designed and consumed in a combustion chamber. The total end surface, or any unit area of it, would burn uniformly in an axial direction, cigarette fashion, so that the surface of the grain at any time would be parallel to the original surface

The linear rate of burning can be expressed either in inches per second(US and GtBrit) or in millimeters(or centimeters) per second(or minute) (Europe, Asia & South America)
*Refs:* 1)Glossary of Ord(1959), 172 2)Rocket Enclycl(1959), 253

**Burning Rates of Explosives.** See under Burning and Burning Characteristics of Explosives

**Burning Rates of Propellants.** See under Burning and Burning Characteristics of Propellants

**Burning Rates of Safety Fuses.** Safety fuses, manufd by Ensign-Bickford Co, Simsbury, Conn, and others, are made in two speed ranges, namely ca 129sec/yd and ca 90sec/yd
*Ref:* Blasters'Hdb(1952), 89
[See also D.Harrington & R.G.Warncke in USBurMines InfoCircular IC **7281**, Washington, DC(1944)]

**Burning, Regressive(or Degressive).** In general, it is the burning of a solid proplnt of such granulation that its surface area decreases during burning(Ref 1 & 2)

In rocketry, the term means the consumption of a solid proplnt chge in a rocket thrust chamber in a manner that results in a gradually decreasing gas pressure at the region of the nozzle approach (Ref 3)
*Refs:* 1)Ohart(1946), 23 2)Glossary of Ord(1959), 91 3)Rocket Encycl(1959), 64

**Burning Shots**(Delayed Shots). When the detonation wave(produced by an initiator) is too weak to explode the charge(such as Dynamite), it frequently sets the chge on fire. The resulting burning charge might evolve toxic fumes. If a burning chge is seen or suspected, the location should not be approached for at least one hour
*Ref:* Blasters'Hdb(1952), 255

**Burning Time** is the time during which a combustible substance(such as a propellant) is consumed by burning

**Burning Time and Equivalent Heat of Exothermic Mixtures.** *Equivalent heat* is the number of kcal liberated per chem equivalent, on reaction of an oxidizing agent and fuel. The greater the equivalent heat, the shorter is the burning time

Based on this rule, G.C.Hale and D.Hart formulated several fuze powders and listed them in USP 2468061(1949) & CA **43**, 5189(1949)

**Burning Time of a Rocket(or Jato) Motor.** There are several different terms used to designate "burning time"
a)*Total burning time* is the time elapsed from ignition of the proplnt until its complete consumption. This time is also known as *firing duration*
b)*10-Percent burning time*, as used at PicArsn, may be defined as the time interval between the point where the thrust(on a curve thrust vs time) reaches 10% of the maximum value and the corresponding 10% point on the descending portion of the curve. This time is also known as *action time* or *actuation duration*(Ref, pp 14,62,140-1 & 163-4)

This value was adopted because the beginning and end portions of the curve(thrust vs time or pressure vs time) are of little significance
c)*"Hercules" burning time*, as used at the Allegheny Ballistics Laboratory, may be defined as the time interval from the instant the thrust has risen to 10% of its max value to a point where the thrust begins to drop sharply near the end of the burning operation. This time is designated in Ref,p 62 simply as *burning time*
d)*50-percent burning time*, as used by the US Army Ordnance, is the interval of firing operation for a solid-propellant rocket propulsion unit during which at least 50% of the equilibrium pressure is obtained(Ref,p 586)
*Ref:* RocketEncycl(1959),14,62,140-1,163-4 & 596
*Note:* It may be mentioned that if the maximum pressure in a rocket(or Jato) motor occurs after 80% of the total *burning time* it is sometimes referred to as the *break-up pressure*

**Burning Train or Igniter Train.** Step-by-step arrangement of charges in pyrotechnic items by which initial fire from the primer is transmitted and intensified until it reaches and sets off the burster charge. Explosive ammunition uses a similar series, called *explosive train*

*Ref:* Glossary of Ord(1959), 154

**Burning, Unstable(in Rocket Motors).** Very often rocket propellants(solid or liquid) burn unevenly (intermittently) with unpredictable periodic high-pressure oscillations in the combustion chamber. These pressure oscillations are of sufficient amplitude to cause distinct humming, squealing or screeching and appear on the oscillograph pressure record in a variety of frequencies and amplitudes. Excessive smoking usually accompanies this phenomenon

Unstable burning is a very serious problem in rocketry because the effective burning time of the rocket is lengthened so much that the trajectory of the round is seriously affected. If it occurs in rockets launched from the ground, the first blast might be just sufficient to move the rocket out of the launcher and then the rocket would be propelled along the ground in an unpredictable manner. The most undesirable feature of the unstable burning is the possibility of damage or even destruction of rocket motor parts(Refs 2,3,14,16 & 17)

When some solid proplnt grains, particularly those with relatively long circular channels available for gas flow, are fired in rockets, there are frequently observed certain *resonating* pressure oscillations, reaching sometimes amplitudes high enough to cause the grain to crack and, in some cases, to ultimately rupture the combustion chamber. When this unstable burning is interrupted suddenly and the incompletely consumed grains are recovered, they exhibit a rippled pattern on the surface of the perforations. As this pattern resembles that of a standing wave, the phenomenon of unstable burning of solid rocket proplnts is usually called *resonance(or resonant) burning*(Ref 14,p 97)

Another term used in conjunction with unstable burning of solid rocket proplnts is *chuffing*. This usually refers to an unstable condition in burning when the chamber pressure drops below minimum value necessary to sustain the burning processes(Ref 16,p 88)

It has been found that there are several methods to stabilize the burning in central perforations of rocket proplnts. The most common method is the drilling of radial holes through the grain web at even intervals along the axis, as described in detail in Ref 3,pp 124-7. Another method of stabilization is insertion of a rod of nonburning material in the center of the axial perforation of the grain(Ref 3,p 128). A third method of stabilizing the reaction of a tubular grain is to make the axial perforation noncircular in cross section. Noncircular perforations have not been used in rockets for the US armed forces because the relation betw burning area and distance burned for grains of such shapes does not result in pressure-time curves which are as satisfactory as those obtained from grains with radial holes(Ref 3,pp 129-30)

In regard to unstable burning in liquid rocket proplnts, some investigators, such as Ross & Datner(Ref 8), distinguish two main types of instability. The most common type, *chugging*, occurs at constant low frequencies between 40 & 200cps(cycles per second), while the other type *screaming*, occurs at frequencies in excess of 10000cps. Chugging can often be eliminated by changes in mixture ratio or injector pressure drop. Screaming is a more serious problem and is difficult to eliminate. The high frequencies of screaming usually result in exceedingly high heat transfer rates to chamber and nozzle walls, so severe in some cases as to cause destruction of the components(See also Ref 14,pp 104-5)

Considerable efforts have been made in attempts to explain unstable burning theoretically. The earliest investigator of this phenomenon in solid homogenious(NC-NG) proplnts was Grad(Ref 1). His theory is also explained by Warren(Ref 14,p 97). Later investigators were Smith & Sprenger(Ref 7), Cheng(Refs 9 & 11) and Green(Refs 10 & 12). Delacarte(Ref 15) investigated unstable burning of *composite* proplnts(see also Ref 14,p 98)

In regard to liquid rocket proplnts, the earliest theory of unstable burning was that of Summerfield(Ref 4). This was followed by theories of Crocco(Ref 5), Crocco & Cheng(Ref 6) and Ross & Datner(Ref 8)(see also Ref 14,p 105)

More detailed discussion on unstable burning of solid and liquid rocket proplnts may be found in the books of Sutton(Ref 2), Wimpress(Ref 3), Warren(Ref 14), Herrick(Ref 16) and Merrill(Ref 17)

This section was reviewed by Dr J.P.Picard

*Refs:* 1)H.Grad, CommunPureAppldMath **2**, 79-102 (1949)(Resonance burning in rocket motors 2)G.P. Sutton, "Rocket Propulsion Elements", Wiley, NY(1949), 160-1 3)R.N.Wimpress, "Internal Ballistics of Solid-Fuel Rockets", McGraw-Hill, NY(1950), 27-8, 104-10 & 122-31 4)M.Summerfield, JARS(JetPropn) **21**, 108-14(1951)(A theory of unstable combustion in liquid proplnt rocket motors) 5)L.Crocco, JARS(JetPropn) **21**, 163-78 (1951) & **22**, 7-16(1952)(Aspects of combustion

stability in liquid proplnt rocket motors) 6)L. Crocco & S.I.Cheng, JARS(JetPropn) **23**, 301-13 (1953)(High-frequency combustion instability in rocket motors with concentrated combustion) 7)R. P.Smith & D.F.Sprenger, "Combustion Instability in Solid Propellant Rockets", in "4th Symposium of Combustion", Williams & Wilkins, Baltimore, Md(1953), 893-906 8)C.C.Ross & P.P.Datner, "Combustion Instability in Liquid Propellant Rocket Motors-A Survey", in "Selected Combustion Problems-Fundamentals and Aeronautical Applications", AGARD Pub, Butterworths,London (1954) 9)S.I.Cheng, JetPropn(JARS) **24**, 27-32 & 102-9(1954)(High-frequency combustion instability in solid proplnt rockets) 10)L.Green, JetPropn (JARS) **24**, 252-3(1954)(Unstable burning of solid proplnts) 11)S.I.Cheng, JetPropn(JARS) **25**, 79-81(1955)(On unstable burning of solid proplnts) 12)L.Green, JetPropn(JARS) **26**, 655-9(1956) (Observations on the irregular reaction of solid proplnt charges in rocket motors) 13)L.Green, JetPropn **28**, 483-5(1958)(Some effects of charge configuration in solid proplnt combustion) 14)F.A. Warren, "Rocket Propellants", Reinhold, NY (1958), 97-8 & 104-5 15)J.Delacarte, MP **41**, 267-84(1959)(Study of instability of burning of composite proplnts) 16)J.W.Herrick, Ed, "Rocket Encyclopedia", Aero Publishers, Inc, Los Angeles (1959), 88(Chuffing & chugging) 97, (Combustion instability) & 386-7(Resonant combustion) 17)G. Merrill, Ed, "Dictionary of Guided Missiles and Space Flight", Van Nostrand, NY(1959), 126 (Chuffing and chugging),522(Resonant burning)

**Burnout.** In rocket technology, this term has two meanings: a)The termination of burning of a jet or rocket engine because of exhaustion of fuel. The term should be distinguished from *cut-off*, which implies a cessation of burning brought about by means other than exhaustion of fuel; and b)The rupture or damage done to the combustion chamber because of overheating in combination with high gas velocity. This is also known as *burn-through*
*Refs:*1)DictGuidedMissiles(1959), 105 2) RocketEncycl(1959), 62-3

**Burnout Time** is the time in which a rocket motor exhausts its fuel supply. It is usually measured from the time of ignition
*Ref:* Glossary of Ord(1959), 51

**Burnout Velocity.** See Burnt Velocity

**Burnt**(All-Burnt). A term used in Interior Ballistics to indicate that the proplnt chge is completely consumed and only combustion gases are present. This usually takes place well before emergence of the projectile from the muzzle of the gun. The step which follows is called the *after-burnt* phase. It involves the transformation of energy from the hot proplnt gases at high pressure to the projectile without further addition of energy to the gases(Ref 1)

Calcns of various ballistic values at "burnt" and "after-burnt" periods are given in Refs 2 & 3
*Refs:* 1)Glossary of Ord(1959), 6 & 11 2) Corner, Ballistics(1950), 138-42 3)SACMS, Ballistics(1951), 86-8

**Burn Through.**(See item b) under Burnout

**Burnt Velocity**(Burnout Velocity). The velocity of a rocket, rocket-powered aircraft, or rocket -powered projectile when fuel consumption terminates due to exhaustion
*Refs:* 1)Glossary of Ord(1959), 51 2)Dict GuidedMissiles(1959), 105

**Burp Gun.** A slang term for the *submachine gun*
*Ref:* Glossary of Ord(1959), 51

**Burrowite.** One of the Brit Ammonals used during WWII: AN 74, TNT 16 & Al 10%
*Ref:* AllEnExpl(1946), 85

**Burrows Explosive of 1914.** It contained K nitrate 56, 2,3,4-TNT(obtained by distn of crude liq TNT) 18, Al(30-mesh, porous, jagged-surfaced granules) 18, Amm perchlorate 6 & paraffin wax 2%
*Refs:* 1)F.R.Burrows & J.G.Burrows,BritP 11582(1914) & CA **9**, 3363(1915) 2)Colver (1918), 684 3)F.R. & J.G.Burrows, USP 1301646(1919) & CA **13**,1930(1919)

**Burrows & Hoyt Explosive.** An expl compn suitable for rock blasting: Amm perchlorate 54, Ba nitrate 29.5, Al powder 1.5, Al granules 9 & resin 3 parts
*Ref:* E.H.Burrows & W.Hoyt, USP 1891500 (1932) & CA **27**, 2036(1933)

**Burrows' Inventions.** L.A.Burrows, during his work with the DuPont Co, obt many patents on explosives, igniters, initiators, fuses, explosive rivets, electric squibs, etc

Following is a partial list of his patents as well as those with collaborators, all assigned to the DuPont Co:
1)W.H.Aughey, L.A.Burrows & W.E.Lawson, USP 2086527(1937) & CA **31**, 6466(1937)(Elec blasting initiator) 2)L.A.Burrows, USP 2086530(1937) & CA **31**, 6466(1937)(Elec blasting initiator contg an ignition compn comprising a Pb salt of nitrophenol) 3)L.A. Burrows & W.E.Lawson, USP 2086531(1937) & CA **31**, 6467(1937)(Elec blasting initiator contg Cu acetylide) 4)L.A.Burrows, USP 2086532 (1937) & CA **31**, 6467(1937)(Elec initiator contg LA) 5)L.A.Burrows, USP 2086533(1937) & CA **31**, 6467(1937)(Elec blasting initiator contg an ignition compn comprising Ag and Hg derivs of chlorinated azidodicarbonamidine and NS as a gelatinizer) 6)L.A.Burrows et al, USP 2105635(1938) & CA **32**, 2357(1938)(Ignition compn for elec blasting caps contg an alkyl salt of Pb, such as bis-triethyl Pb styphnate) 7)L.A.Burrows & W.F.Filbert, USP 2118487 (1938) & CA **32**, 5413(1938)(Prepn of polyvinyl nitrate) 8)L.A.Burrows & G.A.Noddin, USP 2123691(1938) & CA **32**, 7268(1938)(A nonviolent, ventless elec blasting squib comprised of a rigid shell contg a base chge, such as Mg & $BaO_2$, capable of generating sufficient heat to fuse a vent in the shell; a juxtaposed chge, such as $BaO_2$, Se & NS, capable of igniting the base chge; and elec connections for firing the juxtaposed chge) 9)L.A.Burrows, USP 2173270 (1940) & CA **34**, 627(1940)(Elec blasting cap contg the double salt of Pb hypophosphite with Pb nitrate as igniter compn) 10)L.A.Burrows, USP 2173271(1940) & CA **34**, 628(1940)(Elec blasting cap contg Ca hypophosphite and $KClO_3$ or $KNO_3$) 10a)L.A.Burrows & W.F. Filbert, USP 2175249(1940) & CA **34**, 888(1940) (Elec blasting initiator of the delay type and comprising a complex salt of Pb nitrate with a Pb salt of nitrophenol) 11)L.A.Burrows & W.E.Lawson, USP 2175250(1940) & CA **34**, 681(1940)(Elec fuze comprising Pb salts of nitrophenols) 12)L.A.Burrows & C.A. Woodbury, USP 2205081(1940) & CA **34**, 7112 (1940)(Elec blasting initiators contg LSt and a soln of NC as ignition chge) 13)L.A.Burrows & C.B.Van Winter, USP 2228339(1941) & CA **35**, 2722(1941)(Elec squib contg a slow ignition chge comprised of smokeless proplnt and an oxidizer with/or without metals such as Al, Mg, Zr, etc) 14)L.A.Burrows & G.A. Noddin, USP 2268372(1941) & CA **36**, 2725-6 (1942)(Ignition compn for elec blasting caps consisting of smokeless proplnt and a Pb salt of 4,6-dinitro-o-cresol) 15)L.A.Burrows et al, USP 2295075(1942)(Elec heating device for expl rivets) 16)L.A.Burrows, CanP 411441 (1943) & CA **37**, 3607(1943)(Blasting initiator contg HNMnt as base chge and DADNPh with an oxidizer as top chge) 17)L.A.Burrows et al, USP 2327763(1943)(Method of firing expl rivets) 18)L.A.Burrows, CanP 411756(1943) & CA **37**, 3943(1943)(Blasting cap contg an igniter chge of LSt/Tetryl, primer chge of LA, base chge and a chge betw the igniter & primer consisting of dead-pressed HNMnt) 19)W.Brün & L.A. Burrows, USP 2341263(1944)& CA **38**, 4448 (1944)(Priming mixts suitable for ammunition) 20)L.A.Burrows et al, USP 2376474(1945) & CA **39**, 3556(1945)(Nitrourea stabilized by blending small amts of non-volatile acid materials, such as oxalic acid, etc) 21)L.A.Burrows, USP 2387742(1945)(Explosive rivets) 22)L.A. Burrows, CanP 428518(1945) & CA **39**, 5080 (1945)(Blasting cap contg PETN as base chge and DADNPh with an oxidizer as top chge) 23)L.A.Burrows, USP 2388901(1945)(Heating device operated like a gasoline torch for expl rivets) 24)DuPont Co & L.A.Burrows, BritP 568109(1945) & CA **41**, 2900(1947)(Initiating compns produced by mixing DADNPh with nitrated polyhydric alcs, such as HNMnt, and a solvent miscible with $H_2O$ in which DADNPh is insol & HNMnt is sol) 25)DuPont Co, L.A. Burrows et al, BritP 572056(1945) & CA **41**, 6724(1947)(Prepn of stable nitrourea) 26)L.A. Burrows, USP 2396152(1946) & CA **40**, 3606-7 (1946)(Blasting cap contg PETN as base chge and DADNPh with HNMnt as top chge) 27)L.A. Burrows & W.E.Lawson, USP 2402235(1946) & CA **40**, 5568(1946)(Blasting cap contg PETN or other HE as base chge and LA or MF blended with a $H_2O$-insol metal soap, such as Ca stearate, as top chge) 28)F.P.Huston, L.A.Burrows & W.E.Lawson, USP 2412886 & 2412887(1946) (Boiler construction using expls) 29)L.A. Burrows, USP 2427899(1948) & CA **42**, 764(1948) (Blasting cap designed to be initiated by a fuse) 30)L.A.Burrows et al, USP 2556465(1951) (Explosive rivets; improvement in construction)

**Burst.** This term might mean: a)An explosion of a projectile, bomb, warhead, demolition chge, etc, or b)A continuous fire from an automatic weapon, such as an aircraft machine gun c) A rupture of a solid proplnt rocket case caused

by excessive combustion pressure
*Refs:* 1)Glossary of Ord(1959), 51 2) DictGuidedMissiles(1959), 105

**Burst Center**(Center of Burst). Point in the air around which the bursts of several projectiles fired from AA guns under like conditions are evenly distributed
*Ref:* Glossary of Ord(1959), 63

**Burst Diaphragm or Burst Disc**(Blowout Diaphragm or Rupture Disc). A flat circular sheet of frangible material(plastic or metal) installed across the pipe suppling liquid propellant to the thrust chamber of a rocket. The purpose of the disc is to prevent flow of liquid until proplnt pressure builds to a preselected value. The disc then shears open and the proplnt is released to flow

The same type of "valve" has been used for many years as a safety vent on tanks, lines, etc to prevent build-up of undue pressure
*Refs:* 1)RocketEncycl(1959), 64-5 2)Dict-GuidedMissiles(1959), 105

**Bursterberger Explosives.** Dynamite-type expls claimed not to exude, even at 100°, and not to freeze even at minus 14°, were prepd by impregnating spongy substances, such as cellulose, rotten wood or dried mushrooms with chondrin or glycocol(glycine) and then adding 20 to 60% NG
*Ref:* Daniel(1902), 89

**Burster.** A long, plastic or thin-walled metallic container filled with an expl and located in the center of a chemical or smoke shell or bomb. The purpose of a burster is to break open the casing of the shell(or bomb) when the fuze functions so that the chemical or smoke filler is released and dispersed in the vicinity of the burst. For large-caliber chemical shell, a booster is used in addition to the burster
*Refs:* 1)Ohart(1946), 105-6 2)Anon, "Artillery Ammunition", TM **9-1901**(1950), 35 & 376-9 3) Anon, "Ammunition General", TM **9-1900**(1956), 122 & 142 4)USSpecifications MIL-B-13922, MIL-B-11439, MIL-B-11007B, MIL-B-10412, MIL-B-11485B, MIL-B-11211A, MIL-B-20490, MIL-B-12028A, MIL-B-12380 and JAN-B-349

**Bursting Charge**(Main Charge). An explosive charge(filler) in a shell, bomb, grenade, rocket, torpedo, land mine or sea mine that breaks the casing and produces fragmentation or blast effect is known as the bursting or main charge. Explosives required to serve as bursting chges should possess high brisance, power and detonation rate combined with relative insensitivity to impact and heat so that they can be loaded and handled with comparative safety. The explosive in the projectile must be loaded at high densities with a minimum of cavities. If cavities are present to an appreciable extent in the base section of the charge, the *set-back* produced on firing may be sufficient to cause premature explosion in the gun barrel. Cavities might also cause failure of the chge to detonate due to the chge pulling away from the detonator. Bursting chges should not exude when stored at elevated temps.

The conventional method of loading most bursting expls is by casting, but if melting of the expl cannot be achieved at the temp of low-pressure steam(ca 95°), the Amer practice is to use press-loading. Some countries cast -loaded expls with mp higher than 95-100°; for example, PA(mp ca 120°) was cast-loaded in Japan and called Shimose

Bursting chges are detonated by means of boosters which, in turn, are initiated by detonators and primers

Following is a partial list of HE's which have been used in the US as bursting chges: Amatol, Compositions A,B,C & D; Cyclotol, DBX, Edna(Haleite), Ednatol, Explosive D, Minol, Octol, Pentolite, Picratol, Tetrytol, TNT, Torpex and Tritonal. Expls HMX, PETN, PA, RDX and Tetryl have been used in compositions because, alone, they are too sensitive, especially for use in projectiles
*Refs:* 1)Ohart(1946), 36 2)Anon, "Artillery Ammunition", TM **9-1901**(1950), 35-6 & 376-9 3)Glossary of Ord(1959), 64

**Bursting Charge Explosive Train.** See Explosive Train

**Bursting Layer.** A layer of hard material used in the roofs of dugouts or cave shelters in order to cause detonation of projectiles fuzed for short delay or immediate detonation before they can enter deeply enough to cause great destruction
*Ref:* Glossary of Ord(1959), 52

**Bursting Point of NC.** Stable NC begins to *burst* when the decomposition velocity reaches 1.5-3.0 wt % per min. The decompn rate of NC

is proportional to $K = (-U/RT)(1 + 5tU/RT^2)$, where K is const, U the activation energy, R the gas const, t time in mins and T the absol temp at which decompn of NC occurs for the duration of t
*Ref:* S.Watanabe, JChemSocJapan, IndChemSec **58**, 625-7(1955) & CA **50**, 7449(1956)

**Bursting Screens.** Special screens employed in testing boosters and fuzes of artillery ammo. The test consists essentially of firing an item in the vicinity of a screen for the purpose of initiating detonation of the projectile(by means of its impacting against the screen) and for observing the damage inflicted on the screen. The screen may be of a series of wood planks, a piece of sheet metal, cardboard or armor plate
*Ref:* Ordnance Proof Manual No **40-20**, Aberdeen Proving Ground, Md(1943)

**Bursting Type Smoke Shell.** See under Smoke Shells

**Burst Pressure.** According to existing military specifications, it is the particular pressure which(when applied just one time to a rocket component) results in exceeding the ultimate strength of the material involved. Different rocket components might have different burst pressure values
*Ref:* RocketEncycl(1959), 65

**Burst Range.** Horizontal distance from a gun to the point of projectile burst
*Ref:* Glossary of Ord(1959), 52

**Burst Wave or Blast Wave.** Wave of compressed air caused by a bursting bomb or shell(see also under Blast Effects in Air)
*Ref:* Glossary of Ord(1959), 52

**Burton, J**(1868-1924). An Amer industrialist who specialized in the manuf of expls. Organized the Burton Powder Co and the American High Explosives Co
*Ref:* Van Gelder & Schlatter(1927), 26

**Burton's Explosive.** An expl compn patented in 1888 was prepd by mixing pulverized BkPdr with jelly consisting of a mixt of NC with NG or with a soln of shellac
*Ref:* Daniel(1902), 89

**Buse's Explosive.** A permissible exp, patented in England in 1888, consisted of AN with small quantities of permanganates and chromates
*Ref:* Daniel(1902), 89

**Bush**(Flame Bush). A slang term used at proving grounds to signify the pecularly-shaped flame that emerges and arises from the nozzle exit of some thrust chambers of rocket motors after the main control valves have been closed and the primary combustion stopped
*Ref:* RocketEncycl(1959), 65

**Business End of a Blasting Cap.** A colloquial term meaning the end of a cap placed against the explosive charge. It is the solid end of the cap where the "base charge" is located. In caps which utilize the Munroe Effect(the "shaped charge effect"), the business end is indented toward the base charge
*Ref:* A.B.Schilling, PicArsn, Dover, NJ; private communication(1962)

**Butadiene and Derivatives**

**1,3-Butadiene, Bivinyl, Erythrene or Vinylethylene** [called Butadien-(1.3), Divinyl, Erythren, Pyrrolylen or Vinyläthylen in Ger], $CH_2$:CH.CH:$CH_2$; mw 54.09, col, odorless, flammable gas; fr p -108.9°, bp -4.4°, fl p <22°F, auto ign temp 824°F, d 0.621 at 20°, vap d 1.87, vap press 1840mm at 21°; sl toxic with MAC 1000 p/million in air or 2210 mg/$m^3$ of air, expl range 2.0-11.5% concn(Ref 9). It is sol in alc or eth and insol in w. Butadiene is produced from petroleum by catalytic dehydrogenation of normal butylenes at low pressures. The crude product, obtained in yields of 25-30%, is purified by extraction and distillation to give a coml product 98-99% pure. It can be prepd also by dehydrogenation of butane in a one-step process or of ethyl alcohol in a two-step process(Ref 8). Other props & methods of prepn are given in Beil(Ref 1)

Scott(Ref 2) reported that butadiene heated under pressure undergoes violent thermal decompn and in contact with air or O it may form violently explosive *peroxides*. Treatment of butadiene with strong NaOH solns(47%) destroys the peroxides. Butadiene peroxide can be detonated by mild heating or mechanical shock. Solid butadiene absorbs enough O at subatmospheric press to make it detonate violently when heated al above its mp(See also 1,3-Butadiene Peroxide Polymer)

Greenlee(Ref 3) noted that a destructive

expln, including a secondary gas expln, occurred in a Diels-Alder reaction between butadiene & crotonaldehyde under pressure. The accident resulted from failure to mix the reactants before heating. Hanson(Ref 4) reported that this type of expln can be avoided by calcg the liq vol at reaction temp and allowing 20% free space in the autoclave

In the oxidn of $C_4$ hydrocarbons induced by Al borohydride, $[Al(BH_4)_3]$, n-butane gave no expln, 1-butene exploded after an induction period, and 1,3-butadiene exploded immediately (Ref 5). Previous explosions of tank trucks & steel containers caused by filling with butadiene and other liquefied gases in excess of their capacity are discussed by Aull(Ref 6). Measurements of the flammability ranges of butadiene and of other pure combustibles in air were made by Burgoyne & Neale(Ref 7)

*Refs:* 1)Beil **1**, 249, (107), [224] & {929} 2)D.A.Scott, C & EN **18**, 404(1940) & CA **34**, 4571(1940) 3)K.W.Greenlee, C & EN **26**, 1985 (1948) & CA **42**, 6537(1948) 4)E.S.Hanson, C & EN **26**, 2551(1948) & CA **42**, 9179(1948) 5)R.S.Brokaw et al, JACS **72**, 1793(1950) & CA **44**, 5686(1950) 6)H.Aull, Erdöl u Kohle **3**, 195 (1950) & CA **44**, 7539(1950) 7)J.H.Burgoyne & R.F.Neale, Fuel **32**, 5(1953) & CA **47**, 2577(1953) 8)Faith, Keyes & Clark(1957), 171-78 9)Sax (1957), 391 19)CondChemDict(1961), 178

**Mononitrobutadiene**, $C_4H_5NO_2$; mw 99.09, N 14.14%; lacrimatory, col oil having a sweet odor, bp 118-19°, d 1.029 at 20°, $n_D$ 1.4211 at 20°; was obtd on nitrating butadiene with $HNO_3$ (d 1.49-1.50), together with a dimer of butadiene as an impurity. This and other nitroölefins were patented as possible diesel-fuel additives, jet-propulsion fuels, insecticides & for other uses

*Refs:* 1)Beil-not found 2)C.S.Coe & T.F. Doumani, USP 2478243(1949) & CA **44**, 1128(1950)

**Butadiene Nitrosite**, $C_4H_6N_2O_3$; mw 130.10; N 21.53%; formed when large concns of butadiene are mixed with NO, O & N. No other info is given

*Refs:* 1)Beil **1**, {942} 2)M.S.Furman, ZhFiz-Khim **18**, 473(1944) & CA **39**, 2923(1945)

**Butadiene Ozonides.** A monoözonide, $C_4H_6O_3$, wh amor solid, non-expl, was prepd by bubbling ozone into a soln of butadiene in petr eth; the diozonide, $C_4H_6O_6$, very unstable & expl, was not isolated but was prepd by bubbling ozone into a soln of butadiene in chlf; on standing, the diozonide decompd with the formation of oxalic acid

*Refs:* 1)Beil **1**, {940} 2)C.C.Spencer et al, JOC **5**, 615-6(1940) & CA **35**, 1043(1941)

**Butadiene Ozonide Polymer**, $(C_4H_6O_3)_x$, wh solid, very expl; on boiling with w forms an aldehyde; was prepd by Harries(Refs 1 & 2). The normal butadiene rubber(caoutchouc), $[(C_8H_{12})_x]$, forms a monoözonide, $C_8H_{12}O_4$, a diozonide, $C_8H_{12}O_6$, and an ozone oxide, $C_8H_{12}O_4$, which is solid and highly expl(Refs 1,2 & 3)

*Refs:* 1)Beil **1**, (109) 2)C.Harries, Ann **383**, 206(1911) & CA **5**, 3519(1911); Ann **395**, 259 (1913) & CA **7**,1984(1913)

**Butadiene Peroxide.** See under 1,3-Butadiene

**Butadiene Peroxide Polymer**, $-\left[\begin{matrix}-CH.CH_2.OO-\\ | \\ CH:CH_2\end{matrix}\right]-$ $[-CH_2.CH:CH.CH_2.OO-]-_y$, x mw 700-850. It was mentioned under 1,3 -Butadiene that Scott prepd an extremely expl product by peroxidation of 1,3-butadiene, but its structure was not detd(Ref 2). Handy & Rothrock(Refs 3 & 4) prepd,by peroxidation of a soln of 1,3-butadiene in benz at 85-95°, a relatively stable benz soln of polymeric peroxide which could be stored for several weeks at RT. Careful evapn of the solvent under reduced pressure produced a pale yel, sl viscous, oil, $n_D$ 1.5052 at 25°. This oil or its concd soln in benz can be detonated by ignition or severe shock

*Refs:* 1)Beil-not found 2)D.A.Scott, C & EN **18**, 404(1940) 3)C.T.Handy & H.S.Rothrock, JACS **80**, 5306-7(1958) 4)E.G.E.Hawkins, "Organic Peroxides", VanNostrand, Princeton, NJ,(1961), 267-8

**Butagas.** Trade name for compressed butane

**Butaldehyde.** Same as Butyraldehyde

**Butanal.** Same as Butyraldehyde

**Butanamide.** Same as Butyramide

### n-Butane and Derivatives

*n-Butane, Butyl Hydride, Methylethylmethane or Tetrane*(called Butan in Ger), $CH_3(CH_2)_2CH_3$; mw 58.12; col gas, fr p -138.3°, bp -0.5°, fl p -76°F, auto ignition temp 806°F, d of liq 0.599 at 0°, d of vap 2.07 at 0°, vap press 2 atm at 18.8°, sl toxic; expl range air 1.6-6.5% concn; sol in alc, eth or w. Butane occurs in crude petroleum or is formed during its distillation;

it can be prepd by many methods(Ref 1)

Butane is used as producer gas, raw material for motor fuels, and in manuf of synthetic rubber or other org syntheses. It forms various nitro compds and other derivs. Liq butane was proposed by Wulff(Ref 2) for use in expl mixts with a solid oxidizer, silica gel & Al powd

The growing use of liq mixts of butane with ethane and propane requires safety precautions in order to prevent explns, especially in residences(Ref 8). This mixt is very dangerous because its expln limits are low, 2 to 9% vs 9 to 30% for illuminating gas. Further danger lies in the low water pressure reqd to extinguish its flame at the burner surface and in the low flame-propagation velocity which makes it even easier to extinguish. It is suggested that some strong-smelling substance be added to mixts of butane, ethane and propane in order to easily detect the presence of unburned vapors

*Refs:* 1)Beil **1**, 118, (37), [79] & {261} 2)R. Wulff, USP 1772695(1930) & CA **24**, 5160(1930) 3)Thorpe **2**(1938), 172 4)Hackh's(1944), 149 5)Kirk & Othmer **7**(1951), 639 6)Merck(1952), 170 7)EncyclBritannica **4**(1952), 59 8)Anon, Explosivst **1956**, 93 9)Sax(1957), 391-2 10) CondChemDict(1961), 178

**Azidobutane or Butyl Azide**, $C_4H_9N_3$; mw 99.14, N 42.39%. Two isomers exist: *1-Azidobutane or n-Butyl Azide*, col liq, bp 106.5° at 760mm, d 0.865 at 29.5°, $n_D$ 1.415 at 29.5°; forms an azeotrope with methanol boiling at 68°(Ref 3); and *d-2-Azidobutane*, col liq, bp 85° at 500mm, d 0.862 at 25°, $n_D$ 1.4122 at 25°; was prepd by the action of $NaN_3$ on butyl iodide(Ref 2). Their expl props were not detd

*Refs:* 1)Beil **1**, [305] 2)P.A.Levene et al, JBiolChen **115**, 415-18(1936) & CA **30**, 8174-5 (1936); JChemPhys **5**, 985-8(1937) & CA **32**, 1151(1938) 3)J.H.Boyer & J.Hamer, JACS **77**, 952(1955) & CA **50**, 1826-7(1956)

**1-Diazobutane**, $CH_3.CH_2.CH_2.CH{:}N{:}N$; mw 84.12, N 33.30%; amber-colored liq with unpleasant odor; was prepd by warming N-nitroso -N-butylurethane with alc KOH or by direct addn of N-nitroso-N-butylurea to 70% KOH cooled to 0°(Ref 1). Other methods of prepn are given in Refs 2 & 3. Feltzin et al(Ref 4) studied the decompn kinetics of 1-diazobutane and reported an activation energy of 20.6 kcal/mole in the temp range 3-22°. Its expl props were not investigated

*Refs:* 1)Beil **1**, (346) 2)A.F.McKay et al, CanJRes **28B**, 683-8(1950) & CA **45**, 4646 (1951) 3)Ya.Yakubovich & V.A.Ginsberg, ZhObshchKhim **22**, 1534-42(1952) & CA **47**, 9255(1953) 4)J.Feltzin et al, JACS **77**, 206-10 (1955) & CA **49**, 4388(1955)

*Mononitrobutane*, $C_4H_9NO_2$; mw 103.12, N 13.58%. The 1- and 2-mononitro isomers, both liquids, are described in the literature(Refs 1 & 2)

*Refs:* 1)Beil **1**, 123, [87] & [303-4] 2)Sax (1957), 946

*2-Nitroso-2-nitrobutane*, $CH_3.C(NO_2)(NO).C_2H_5$; mw 132.12, N 21.20%; wh prisms(from chlf), mp 58°; insol in w or alc; other props & methods of prepn are given in the Ref

*Ref:* Beil **1**, 124

**Dinitrobutane**, $C_4H_8N_2O_4$; mw 148.12, N 18.91%. The following isomers are described in the literature: *1,1-Dinitrobutane*, oil, bp 197° (partial decomp); forms salts which are not expl; *1,2-Dinitrobutane*, liq, bp 90-92° at <1mm (Refs 3 & 3a); *1,4-Dinitrobutane*, col & odorless liq, bp 176-8° at 13mm(Refs 2 & 6); *2,2-Dinitrobutane*, inert oil, bp 199°(Refs 1 & 5); and *2,3-Dinitrobutane*, col prisms(from eth), mp 41°, dec ca 150°(Refs 2 & 3). Other props & methods of prepn are given in the Refs

*Refs:* 1)Beil **1**, 124 2)Beil **1**, (40) & {305} 3)Beil **1**, {305} 3a)A.E.Wilder-Smith et al, BritP 580260(1946) & CA **41**, 2069(1947) 4)C.T. Bahner, USP 2485803(1949) & CA **44**, 2876(1950) 5)C.T.Bahner, IEC **44**, 317(1952) & CA **46**, 4930(1952) 6)H.Feuer & G.Leston, OrgSynth **34**, 37-9(1954) & CA **49**, 5266(1955)

**1,1,1-Trinitrobutane**, $C_4H_7N_3O_6$, described in Conf US Rubber Co Quarterly Rpt No **25**,p 10 (Nov 1953 to Feb 1954)

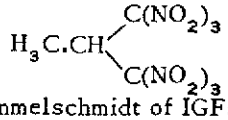
**2,2,3,3-Tetranitrobutane**, $H_3C.C(NO_2)_2.C(NO_2)_2.CH_3$; mw 238.12, N 23.53%; wh crysts, mp 159-163° (dec); was prepd by nitrating dimethylglyoxime or by the addn of nitrogen dioxide to 2,3-dinitro -2-butene(Refs 4 & 5). According to Gabiel et al (Ref 5), the compd reported by Miller & Hunt (Ref 2) was not a tetranitrobutane but a trinitro compd melting at 119-20°

The expl props & performance of this compd are described in Conf Repts(Refs 3 & 6) and others

*Refs:* 1)Beil **1**, {305} 2)A.J.Miller & H.Hunt, JPhysChem **49**, 21(1945) & CA **39**, 1352(1945) 3)A.D.Little, "Second Rpt on Synthesis &

Testing of HE's",pp 18,31,33,59,270 & 272 (March 1951)(Conf) 4)J.S.Belew et al, JACS **77**, 1111(1955) & CA **50**, 1648(1956) 5)C.E. Grabiel et al, JACS **77**, 1294(1955) & CA **50**, 1571(1956) 6)A.D.Little, "Fourth Rpt on Synthesis & Testing of HE's"p 111(1956)(Conf)

**Hexanitrobutane or 1,4-Di(trinitro) butane,** $(O_2N)_3C.CH_2.CH_2.C(NO_2)_3$; mw 328.12, N 25.62%; was believed to be obtd in admixt with *hexanitroisobutane,*



in 1945 by Dr Schimmelschmidt of IGFarbenind when acetylene gas was bubbled into nitroform contg a little mercuric nitrate. The following reactions are supposed to take place:

$$HC{:}CH + CH(NO_2)_3 \rightarrow CH_2{:}CH.C(NO_2)_3$$

$$2CH_2{:}CH.C(NO_2)_3 + 2CH(NO_2)_3 \rightarrow CH_3.CH[C(NO_2)_3]_2 + (O_2N)_3C.CH_2.CH_2.C(NO_2)_3$$

Both of these compds are very powerful expls and were believed to be present in tetranitromethane & nitroform when a reduced flow of acetylene occurred in the main reaction of IGFarbenind's method of prepg TeNMe & nitroform from acetylene & $HNO_3$. Attempted prepn of HeNBu by the US Rubber Co is described in Ref 4

*Refs:* 1)Beil-not found 2)CA-not found(thru 1956) 3)W.Hunter, "The Production of Tetranitromethane and Nitroform", IGFarbenind, Höchst-am-Main, BIOS Final Rpt **709**, Item 22,8-9(1946) & PB Rpt No **47730**, OTS Bibliography of Scientific and Industrial Reports vol **4**, 1041(1947) 4)US Rubber Co, Quarterly Progress Rept No 6, Contract Nord **10129**, Passiac, NJ(1948), 28-9

### iso-Butane and Derivatives

*iso-Butane, 2-Methylpropane or Trimethylmethane,* (called Isobutan, 2-Methyl-propan or Trimethylmethan in Ger), $(CH_3)_3CH$; mw 58.12, col gas, fr p -159.6°, bp -11.7°, fl p -83°, d 0.557 at 20°; other props & methods of prepn are given in Beil(Ref 1)

iso-Butane occurs as an important component of natural gasoline, refinery gases, "wet" natural gas and can be obtd by isomerization of n-butane. It is used in org synthesis, as a refrigerant, fuel, as starting material for liq fuel synthesis and as an aerosol propellant(Ref 3)

The general expln hazards of iso-butane were detd by Jones & Scott(Ref 2). Gaseous mixts were ignited by sparks from a high-voltage induction coil. The limits of its flammability in air are 1.83% and 8.4% by vol; min ign temp in air is 462°, in oxygen 319°. The addn of N (39.8%, or more) or of $CO_2$(26% or more) to iso-butane-air mixts produces nonflammable mixts provided the concn of O is a min and the concn of iso-butane is less than 2.5%

*Refs:* 1)Beil **1**, 124, (40), [87] & {305} 2)G.W. Jones & G.S.Scott, BurMines RI **4095**(1947) & CA **41**, 6723(1947) 3)CondChemDict(1961), 621

*β-Nitroso-iso-butane or 2-Nitroso-2-methylpropane,* $(CH_3)_3C.NO$; mw 87.12, N 16.08%; wh ndls, mp 76-76.5°(in a sealed tube), and distills at 80-2°; in an open tube sublimes w/o melting; was prepd by oxidizing ter-butylamine with cold Caro's persulfuric acid

*Refs:* 1)Beil **1**, 129 & {327} 2)E.Bamberger & R.Seligman, Ber **36**, 685(1903) & JCS 84 I, 322(1903)

*Mononitro-iso-butane,* $C_4H_9NO_2$; mw 103.12, N 13.58%. The 1-nitro and 2-nitro isomers of 2-methylpropane are described in the literature

*Ref:* Beil **1**, 129, (42) & {327}

**Dinitro-iso-butane,** $C_4H_8N_2O_4$; mw 148.12, N 18.91%. Two isomers are described in the literature: *1,1-Dinitro-2-methylpropane or α,α-Dinitro-isobutane,* $(CH_3)_2CH.CH.(NO_2)_2$, non-volatile oil; forms K & Ag salts which are not expl(Ref 1); and *1,2-Dinitro-iso-butane,* $(CH_3)_2C(NO_2).CH_2.NO_2$, wh cryst solid(from MeOH), mp 52-3°, bp 92° at 1mm, was obtd as the primary product in the reaction between iso-butylene & dinitrogen tetroxide in ether or ester medium(Refs 2 & 4). This compd is a mild expl(51% of Blasting Gelatin by Ballistic Mortar Test); very insensitive to friction or impact; and is stable in storage at RT 50° & on heating in vacuum at 100° for 40hrs(Ref 1a & Ref 4,p 57)(See also Ref 5)

*Refs:* 1)Beil **1**, 130 1a)Beil **1**, {328} 2)A.E. Wilder-Smith et al, BritP 580260(1946) & CA **41**, 2068-9(1947) 3)C.W.Scaife et al, BritP 590513(1947) & CA **42**, 2984(1948)(Reaction with $NH_3$, urea,or EtONa) 4)N.Levy et al, JCS **1948**, 52-60 & CA **42**, 4906(1948) 5)A.E. Wilder-Smith et al, USP 2472550(1949) & CA **43**, 6646-7(1949)

**1,4-Butanedicarboxylic Acid.** See Adipic Acid, Vol 1,p A104-L

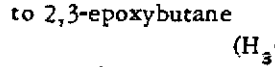
### Butanediol and Derivatives

**Butanediol, Butylene Glycol or Dihydroxybutane,**

$C_4H_{10}O_2$; mw 90.12. Four isomers are described in the literature: *α or 1,2-Butanediol,* $C_2H_5.CH(OH).CH_2OH$(Refs 1 & 5,p 404); *β or 1,3-Butanediol,* $CH_3.CH(OH).CH_2.CH_2.OH$ (Refs 2 & 5,p 405); *γ or 1,4-Butanediol* (Tetramethylene Glycol), $HO(CH_2)_4OH$(Refs 3 & 5,p 392); and *ψ or 2,3-Butanediol,* $CH_3(CH.OH)_2CH_3$(Refs 4 & 5,p 405). All are col liquids; their props & methods of prepn are given in the Refs

*Refs:* 1)Beil **1**, 477, [544] & {2165} 2)Beil **1**, 477(248), [545] & {2167} 3)Beil **1**, 478, (249), [545] & {2172} 4)Beil **1**, 479, (249), [546] & {2178} 5)Sax(1957), 392, 404, 405

**2,3-Butanediol-3-nitrate**(Nitratobutanol), $CH_3.CH(OH).CH.(ONO_2)CH_3$; mw 135.12, N 10.37%; liq, bp 44-5° at 1mm, d 1.811 at 29°, $n_D$ 1.4382 at 20°; was prepd by adding $HNO_3$ to 2,3-epoxybutane



($H_3C.CH$—$CH.CH_3$).

Some of the nitrato alcohols are high expls, for example, the 2-nitratoethanol detonated at 187°, the nitratopropanol under the same conditions decompd; results of the thermal sensitivity of the nitratobutanol were not reported

*Refs:* 1)Beil-not found 2)P.L.Nichols, Jr et al, JACS **75**, 4255-58(1953) & CA **48**, 11296(1954)

**Butanediol Dinitrate or Butylene Glycol Dinitrate**, $C_4H_8N_2O_6$; mw 180.12, N 15.55%. Four isomers are described in the literature: *1,2-Butanediol Dinitrate,* $C_2H_5CH(ONO_2)$-$CH_2(ONO_2)$, liq, bp 114-15° at 11mm(Ref 1,p {2166}); *1,3-Butanediol Dinitrate,* $(O_2NO)CH_2.CH_2.CH(ONO_2).CH_3$, lt yel oil, very volatile, d 1.309 at 22°, $n_D$ 1.4479 at 17.5°; viscosity & index of refraction(Refs 13); prepn(Ref 1,p {2172}) & Ref 6); impact sensitivity 2.5-3.0 vs 0.42-0,40 for NG(Refs 10 & 11); was used by Hibbert(Ref 2) in expl mixts and by Tranchant(Ref 12) as substitute for NG in double-base propellants; and *1,4-Butanediol Dinitrate,* $(O_2NO)CH_2.CH_2.CH_2.$-$CH_2(ONO_2)$, lt yel oil, very vol, d 1.335 at 16°, $n_D$ 1.4500 at 21.2°(Ref 1,p {2176}) & Ref 13); impact sensitivity 3.10 vs 0.40 for NG(Ref 11); and levo-*2,3-Butanediol Dinitrate,* $CH_3.CH$-$(ONO_2).CH(ONO_2)CH_3$, oily liq, fr p 0-4°, bp 91.5° at 10mm, d 1.297 at 20°, $n_D$ 1.4405 at 20°; insol in w; was first prepd by nitrating levo-2,3-butanediol at 0-5°(Ref 5). See also Ref 1,pp {2183 & 2187}. It is an expl comparable in impact sensitivity to TNT and in stability to NG; a sample in storage for 4 yrs gave an Abel Heat Test value of 2 mins at 100°C vs 10+ mins for NG at 82.2°. It was found to be a poor gelatinizer for NC of 13.1% N(Ref 9). See also discussion in Refs 3,4,7,8 & 14

*Refs:* 1)Beil **1**, {2166,2172,2176,2183,2187} 2)H.Hibbert, USP 994841 & 2(1911) & CA **5**, 2724(1911) 3)Brunswig, Props(1926), 14 & 22 4)Naoúm, NG (1928), 238-9 5)C.Matignon et al, MP **25**, 176,184(1932-33) 6)(?)Aubry, MP **25**, 194(1932-33) 7)Davis(1943), 235 8)P.F.Macy & A.A.Saffitz, "Explosive Plasticizers for Nitrocellulose", PATR **1638**(Feb 1947)(Prepn and lab tests of stability & sensitivity) 9)A.F. McKay et al, JACS **70**, 430(1948) & CA **42**, 2228(1948) 10)P.Aubertein, MP **30**, 21(1948) & CA **45**, 353-5(1951) 11)L.Médard, MP **31**, 131-43(1949) & CA **46**, 11685(1952) 12)J. Tranchant, MP **32**, 313-18(1950) & CA **47**, 9014(1953) 13)L.Boileau & M.Thomas, MP **33**, 155-7(1951) & CA **47**, 5200(1953) 14)Belgrano (1952), 91

**Butanediol Dinitrite**, $C_4H_8N_2O_4$; mw 148.12, N 18.91%. Three isomers are described in the literature: *1,3-Butanediol Dinitrite,* $(ONO).CH_2.CH_2.CH(ONO).CH_3$, liq, bp 52° at 41mm, d 1.075 at 25°, $n_D$ 1.3968 at 25°; thermal decompn products are acetaldehyde, ethylene & propylene(Ref 3); *1,4-Butanediol Dinitrite,* $(ONO)CH_2.CH_2.CH_2.CH_2(ONO)$, liq, bp 70° at 44mm, d 1.166 at 25°, $n_D$ 1.4028 at 25°; thermal decompn products are NO & γ-hydroxybutyraldehyde(Ref 3); and *2,3-Butanediol Dinitrite,* $CH_3.CH(ONO).CH(ONO).CH_3$, liq, bp 42° at 50mm, d 1.066, $n_D$ 1.3938 at 20°; thermal decompn in the vapor phase gives NO & acetaldehyde while in the liq phase the products are acetaldehyde, biacetyl, 2-butanol-3-one & 2,3-butanediol(Ref 2). These compds were prepd from the corresponding diols by std lab precedures. Their inhalation produces headaches

*Refs:* 1)Beil-not found 2)L.P.Kuhn & L. DeAngelis, JACS **76**, 328-9(1954) & CA **49**, 2996(1955) 3)L.P.Kuhn et al, JACS **78**, 2719-22(1956) & CA **50**, 14506(1956)

*2-Nitro-1,4-Butanediol,* $HO.CH_2.CH_2.CH(NO_2).$-$CH_2.OH$, is known in the form of its Na salt, crysts(from methanol)

*Ref:* Beil **1**, {2177}

**1,4-Dinitro-2,3-butanediol**, $O_2N.CH_2.CH(OH)$-$.CH(OH).CH_2.NO_2$; mw 180.12, N 15.55%; crysts(from 1,1-chloronitroethane), mp 134°; was prepd from nitromethane, aq glyoxal$(CHO)_2$, methyl alc & NaOH in w kept 1 hr at 10° and neutralizing the soln with acetic acid; the

nitromethane extract was evap in vacuo. No expl props were reported

*Refs:* 1)Beil-not found 2)H.Plaut, USP 2616923(1952) & CA **49**, 11701(1955)

**1,1,4,4-Tetranitro-2,3-butanediol**, $(O_2N)_2CH.CH(OH).CH(OH).CH(NO_2)_2$; mw 270.12, N 20.74%; brn liq; was first prepd from the di K-salt of dinitromethane in w and glyoxal. This compd is considered a useful intermediate, fuel, or expl ingredient

*Refs:* 1)Beil-not found 2)H.Plaut, USP 2544103(1951) & CA **45**, 7587(1951)

**1,1,1,4,4,4-Hexanitro-2,3-methoxybutanediol**, $(O_2N)_3C.CH(OCH_3).CH(OCH_3).C(NO_2)_3$, is described in Conf EngrgResInst 2nd Quart Prog Rept (March 1954) and abstracted in US Rubber Co 1st QuartProgRept No **26**(Contract NOrd 10129 & 12663)

**iso-Butanediol and Derivatives**

**iso-Butanediol, iso-Butylene Glycol, asym -Dimethylethylene Glycol, Methyl-propanediol or Methyltrimethylene Glycol**, $C_4H_{10}O_2$; mw 90.12. Two isomers are described in the literature: *2-Methyl-1,2-propanediol*, $(H_3C)_2C(OH).CH_2.OH$ (Ref 1,pp 480, (250) & [547]) and *2-Methyl -1,3-propanediol*, $OH.CH_2.CH(CH_3).CH_2.OH$(Ref 1,pp 480 & {2189})

*Ref:* Beil **1**, 480, (250), [547] & {2187, 2189}

*Nitro-iso-butanediol or 2-Nitro-2-methyl-1,3 -propanediol*, $HO.CH_2.C(NO_2)(CH_3).CH_2.OH$, mw 135.12, N 10.37%; monoclinic crysts, mp 147-50°, dec on heating under 10mm pressure; readily sol in w or alc; was prepd by addg a little $KHCO_3$ to a mixt of nitroethane, formaldehyde & w

*Ref:* Beil **1**, 480, [547] & {2190}

**Nitro-iso-butanediol Dinitrate or 2-Nitro-2-methyl -1,3-propanediol Dinitrate**, $(O_2NO)CH_2.C(NO_2)(CH_3).CH_2(ONO_2)$; mw 225.12, N 18.67%; col crysts, mp 39.5°; $Q_c^v$ 528.2 & $Q_f^v$ at 18° 86.1 kcal/mole(Ref 7); toxic effect is as a vasodilator, less active than NG but shows a more lasting effect(Ref 8); was prepd by nitrating the corresponding alc(Refs 3,4 & 5)(See also Ref 2a)

Médard(Ref 6) reported its expl & other props as follows:

*Density at Various Pressures:*

| Pressure, kg/cm² | 1.360 | 2.210 | 2.720 |
|---|---|---|---|
| Density, g/cc | 1.58 | 1.595 | 1.61 |

*Impact Sensitivity*, a 2-kg wt falling from a height of 1.75m produced 60% explns vs 56% for Tetryl

*Power by Trauzl Test*(CUP) 140.3 vs 100 for PA

*Sensitivity to Initiation*, readily detonated in the liq state by a No 8 blasting cap as was its 50/50 mixt with DNT

*Stability*, not satisfactory for most purposes

Bergeim(Ref 2) in 1928 patented an expl compn contg nitro-iso-butanediol dinitrate, NG, $NaNO_3$, woodmeal, $CaCO_3$ & NC. This compd has also been used as an antifreeze agent and as a component of some expls

*Refs:* 1)Beil-not found 2)F.H.Bergeim,USP 1691955(1928) & CA **23**, 708(1929) 2a)M.S. Fishbein, VoennayaKhim **1933**, No 6,3-8 & CA **29**, 7077(1935)(A review) 3)W.deC. Crater, USP 2112749(1938) & CA **32**, 3964(1938) 4)H.J. Hibshman et al, IEC **32**, 427-9(1940) & CA **34**, 3234-5(1940) 5)J.A.Wyler, USP 2195551(1940) & CA **34**, 5283(1940) 6)L.Médard, MP **35**, 111-12 (1953) & CA **49**, 5842(1955) 7)L.Médard & M. Thomas, MP **36**, 97-127(1954) & CA **50**, 3763 (1956) 8)J.Sallé, MP **36**, 305-7(1954) & CA **49**, 16218(1955)

**Butanetriol and Derivatives**

**Butanetriol, Methyl Glycerol or Trihydroxybutane**, $C_4H_{10}O_3$; mw 106.12. Two isomers are described in the literature: *1,2,3-Butanetriol*, $CH_3.CH(OH).CH(OH).CH_2.OH$; hygr liq with burning taste, bp 162.5-63.5° at 15mm(Ref 1); and *1,2,4-Butanetriol*, $CH_2(OH).CH_2.CH(OH).CH_2.OH$; syrupy liq with sweet burning taste, bp 190-1° at 18mm(Refs 2 & 4). Other props & methods of prepn are given in the Refs. These compds yield expl substances when nitrated

A new two-step synthesis of 1,2,4 -butanetriol from allyl alc and formaldehyde is described in Ref 3

*Refs:* 1)Beil **1**, 519, [596] & {2243} 2)Beil **1**, 519, (276), [596] & {2344} 3)US Rubber Co, Quarterly Progress Rept No 3, Contract NOrd **10129**, Passaic, NJ(1948), 2-9 4)Sax(1957), 392

**Butanetriol Dinitrate**, $C_4H_8N_2O_7$; mw 196.12, N 14.29%. Two isomers are described in the literature: *1,2,3-Butanetriol Dinitrate*, $CH_3.CH(ONO_2).CH(OH).CH_2(ONO_2)$; liq expl intermed, obtd by Fichter & Herndl(Ref 2), together with other dinitrates, by the electrolysis of adipates with a Pt electrode in the presence of $NO_3$ ion; and *1,2,4-Butanetriol Dinitrate*, $CH_2(ONO_2).CH_2.CH(OH).CH_2(ONO_2)$; liq expl intermediate, obtd as above(Ref 2)

*Refs:* 1)Beil-not found 2)F.Fichter & J.Herndl,

Helv **25**, 229(1942) & CA **36**, 5713(1942)
**Butanetriol Trinitrate**, $C_4H_7N_3O_9$, mw 241.12, N 17.43%. Two isomers exist: *1,2,3-Butanetriol Trinitrate or α-Methyl Glycerol Trinitrate*, $CH_3.CH(ONO_2).CH(ONO_2).CH_2(ONO_2)$; liq, d 1.489; sl sol in w; miscible in alc, eth, acet & 2:1 eth-alc; was prepd by nitrating α-methyl glycerol(Refs 2, 3 & 4). This compd was patented as a substitute for NG, suitable for mixing with NG to lower its fr p and was claimed to be a powerful expl. Its expl props recorded by Blatt(Ref 5) are as follows: *Impact Sensitivity*, 2-kg wt,ca the same as NG(see also Médard, Ref 7); *Power* by Ballistic Mortar Test, ca the same strength as NG when used in mixts; *Thermal Stability* by 82.2° KI Test & Bergmann-Junk Test, ca the same as NG; and *Velocity of Detonation*, 7270 m/sec. This compd and related α-mono & α,α-disubstituted glycerol nitrates have been claimed to be useful expl components

**1,2,4-Butanetriol Trinitrate** or *α,β,δ-Trihydroxybutane Trinitrate*, $CH_2(ONO_2).CH_2.CH(ONO_2).CH_2(ONO_2)$, liq, d 1.520 at 20°, $n_D$ 1.4738 at 20°; sl sol in w; miscible with alc, eth, acet & 2:1 eth-alc; was prepd by nitrating 1,2,4-butanetriol(Ref 6). Due to the fact that this compd is a good gelatinizer for NC, it was used during WWII by the Germans as substitute for NG in double-base proplnts. Its use as a plasticizer for NC was investigated at Picatinny Arsenal by Clarke(Ref 9) and at the US Naval Powder Factory by Gallaghan(Ref 6). Its expl props were reported in Ref 8 as follows: *Impact Sensitivity*, 1-lb wt, ca the same as NG (see also Médard, Ref 7); *Brisance* by Sand Test, ca the same as NG, 49g vs 51.5 for NG; *Explosion Temperature*, 5-sec value in °C, 230°vs 220°for NG; and *Thermal Stability* by Heat, Vacuum Stability and Volatility Tests, more stable than NG

Izzo(Ref 4) discussed the expl props in regard to its use as military or industrial explosive

*Refs:* 1)Beil-not found 2)H.P.Groll, USP 2139364(1938) & CA **33**, 2339(1939) 3)N.V.de Bataafsche Petroleum Maatschappij, FrP 835592(1938) & CA **33**, 4788(1939) 4)A.Izzo, ChimIndAgrBiol **16**, 155(1940) & CA **34**, 4905-6 (1940) 5)Blatt, OSRD **2014**(1944) 6)J.A. Gallaghan et al, "The Synthesis of 1,2,4 -Butanetriol and the Evaluation of Its Trinitrate", USNavalPowdFactoryTechRept No **19**(1948) 7)L.Médard, MP **31**, 143(1949) & CA **46**, 11685(1952) 8)PATR **1740**, Revision **1** (1958),pp 37-40 9)W.G.Clarke, "Evaluation of 1,2,4-Butanetriol Trinitrate as the Liquid Explosive Plasticizer for Cast Double-Base Propellant", PA, FRL Propellant Res Sec Rpt No **4**(1960)(Conf, not used as a source of info)

**iso-Butanetriol and Derivatives**

**iso-Butanetriol, Methyl-propanetriol or Trimethylolmethane**, $C_4H_{10}O_3$; mw 160.12. Two isomers are described in the literature: *2-Methyl-1,2,3-propanetriol or β-Methylglycerol*, $CH_2(OH).C(CH_3)(OH).CH_2.OH$, col vis liq, bp 115-20° at 1.6mm. d 1.186 at 20°, $n_D$ 1.4730 at 20°, can best be prepd by hydration of β-methyl-glycidol(2,3-epoxy-2-methyl-1-propanol), and can be prepd directly from either dichloro-tert-butyl alcohol or β-methylglycerol monochlorohydrin(Ref 2). See also Refs 1,4 & 5); and *2-(Hydroxymethyl)-1,3-propanediol or Trimethylol Methane*, $CH_2(OH).CH(CH_2OH)_2$; was prepd by Fujii(Ref 3) from a mixt of acetaldehyde & formaldehyde(10:25 mol) heated with $Ca(OH)_2$ and the product reduced with H in the presence of Ni

The nitrated products of these compds are expl

*Refs:* 1)Beil **1**, 520 2)G.W.Hearne & H.W. DeJong, IEC **33**, 941(1941) & CA **35**, 5858(1941) 3)S.Fujii, JapP 153925(1942) & CA **43**, 3477 (1949) 4)I.Bergsteinsson, USP 2373942(1945) & CA **39**, 3006(1945) 5)G.W.Hearne & C.G. Schwarzer, USP 2600766(1952) & CA **47**, 1732 (1953)

**Nitro-iso-butanetriol, Trimethylolnitromethane or 2-Nitro-2(hydroxymethyl)-1,3-propanediol**(called "Nitroisobutylglycerin" in Beil), $O_2N.C(CH_2OH)_3$; 151.12, N 9.27%; col ndls or prisms, mp 201° (196° for the crude product); $Q_c^v$ 507.8 kcal/mol & $Q_f^v$ 173.9 kcal/mol(Ref 2); readily sol in w or alc, sl sol in eth; other props & methods of prepn are given in Beil

*Refs:* 1)Beil **1**,520,(276),[596] & {2345} 2)L. Médard & M.Thomas, MP **35**, 158, 172(1953) & CA **49**, 11284(1955)

**Nitro-iso-butanetriol Trinitrate(NIBTN) or Nitroisobutylglycerol Trinitrate**, also called **2-Nitro-2(hydroxymethyl)-1,3-propanediol Trinitrate or Trimethylolnitromethane Trinitrate**(called "Nitroisobutylglycerintrinitrat" in Beil), $O_2N.C(CH_2.ONO_2)_3$, mw 286.12, N 19.58%; yel viscous oil, fr p -39°, d 1.64 at 20°, $n_D$ 1.492 at 20°(Ref 14) and 1.4896 at

25°(Ref 16); $Q_c^v$ 530.5 kcal/mol & $Q_f^v$ 50.0 kcal/mol(Ref 12); volatility lower than for NG, namely, at 25° 0.127 x $10^{-3}$ g/$cm^2$/24 hrs vs 0.153 x $10^{-3}$ for NG. NIBTN is sol in methyl & ethyl alcohols, acet, ether, ethylene dichloride, chlf & benz; insol in w, $CS_2$ & petr eth; toxicity much lower than with NG; it causes only a slight headache; its gelatinizing action on collodion cotton is appreciably less than that of NG, even when hot

NIBTN was first prepd by Hofwimmer(Refs 1 & 2) by condensation of 3 moles of formaldehyde with 1 mole nitromethane in the presence of $KHCO_3$ and subsequent nitration of the product. Modifications of this method are described in Refs 3,4,5,6,10 & 15. Aaronson(Ref 8) investigated the methods existing prior to 1941 and came to the conclusion that Stettbacher's method(Ref 5) was the best

The exp, props of NIBTN, recorded by Stettbacher(Ref 5), Blatt(Ref 9), PicArsnTech-Repts(Refs 8 & 16) and by Médard(Ref 12), are as follows: *Brisance*, by Sand Test, 56g vs 52g for NG, using kieselguhr as absorbent(Ref 16); *Detonation Rate*, 7860 m/sec at d 1.60 vs 7700 at d 1.6 for NG(Ref 16); *Explosion Temperature*, 185°(ignited) vs 222°(expl) for NG(5 sec); *Impact Sensitivity:* Naoúm(Ref 3,p 241) gave 6cm vs 2cm for NG(Kast app, 2-kg wt); Aaronson(Ref 8) - 25cm vs 44cm for NG(BM app, 2-kg wt); later, PicArsn value for NG was given as 15cm(Ref 16) and Médard's tests showed that NIBTN is less sensitive than NG(Ref 12); *Power*, by Trauzl Test, for a mixt with 75% kieselguhr 325cc vs 305cc for a similar NG mixt; for the mixt NIBTN/NC-93/7 580cc vs 600cc for a similar NG mixt(Blasting Gelatin)(Ref 3); *Thermal Stability*. Naoúm(Ref 3) reported its stability at 70-80° to be not less than that of NG, but in Ref 16, its stability by the 82.2° KI test is 2mins vs 10+ for NG

Tranchant(Ref 13) studied the props of NIBTN and incorporated it in double-base proplnts by substituting for NG; Bronstein(Ref 7) patented an expl consisting of NIBTN 25-75 & NS 75-25% together with coating agents

*Refs:* 1)Beil **1**, (277), & {2346} 2)F.Hofwimmer, SS **7**, 43(1912) & CA **6**, 1228(1912) 3)Naoúm, NG(1928), 239-41 4)(?)Aubry, MP **25**, 197-204 (1932-33) & CA **27**, 4083(1933) 5)A.Stettbacher, NC **5**, 159-62, 181-4 & 203-6(1934) 6)G.A. Hunold, SS **30**, 263-4(1935) & CA **29**, 8333 (1935) 7)J.B.Bronstein, Jr, USP 2170629(1939) & CA **34**, 266(1940) 8)H.A.Aaronson, "Study of Explosives Derived from Nitroparaffins", PATR **1125**, (1941) 9)Blatt, OSRD **2014**(1944) (Trimethylolnitromethane Trinitrate) 10) Stettbacher(1948), 69 11)L.Médard, MP **31**, 143(1949) & CA **46**, 11685(1952) 12)L.Médard & M.Thomas, MP **31**, 196(1949) & CA **46**, 11684 (1952) 13)J.Tranchant, MP **32**, 313-18(1950) & CA **47**, 9014(1953) 14)J.Boileau & M.Thomas, MP **33**, 155-7(1951) & CA **47**, 5201(1953) 15) Stettbacher(1952), 94 16)PATR **1740**, Revision 1(1958),pp 223-5

**Nitro-iso-butanetriol Triacetate or 2-Nitro-2-(hydroxymethyl)-1,3-propanediol Triacetate,** $O_2NC(CH_2OOC.CH_3)_3$, was patented in Italy as an ingredient of blasting expl: RDX(or PETN) 75 & nitro-iso-butanetriol triacetate 25%, melted together at 80°

*Ref:* "Montecantini" Società Generale per L'industria Mineraria e Chimica, ItalP 433633 (1948) & CA **44**, 1709(1950)

**Butanoic Acid.** Same as Butyric Acid

## Butanol and Derivatives

**Butanol or Butyl Alcohol**(called Butanol or Butylalkohol in Ger), $C_4H_{10}O$; mw 74.12. Four isomers are known: *n- or Butan-1-ol*, $CH_3(CH_2)_2CH_2.OH$, col liq, fr p -89°, bp 117.7°, d 0.8109 at 20°, fl p 114°F(TOC)(Ref 1; Ref 6,p 396 & Ref 7,p 182); *sec- or Butan-2-ol*, $CH_3.CH_2CH(OH).CH_3$, col liq, fr p -114.7°, bp 99.5°, d 0.808 at 20°, fl p 75°F(CC)(Ref 2; Ref 6,p 396 & Ref 7,p 182); *iso-Butanol*, $(CH_3)_2CH.CH_2.OH$, clear liq, fr p -108°, bp 107°, d 0.805 at 20°, fl p 82° -100°F(COC) (Ref 3; Ref 6,p 793 & Ref 7,p 622); and *tert-Butanol*, $(CH_3)_3C.OH$, low-melting col crysts or liq having the odor of camphor, mp 25.3°, bp 83°, d 0.78 at 20°, fl p 52°F(CC) (Ref 4; Ref 6,p 397 & Ref 7,p 183). These alcohols are of mod toxicity and they represent expln hazards in the following concns in air: n- 1.7 to 18%; sec- unkown; iso- 1.9 to 8.5% and tert- 2.4 to 8.0%(Ref 6). Butanols are used as solvents for resins & coatings and as intermediates in org synthesis. According to Tavernier(Ref 5), butanol was used a a solv in the prepn of some French proplnts

*Refs:* 1)Beil **1**, 367, (186), [387] & {1480} 2)Beil **1**, 371, 373, (188, 189), [400,404,405] & {1527} 3)Beil **1**, 373, (189), [405] & {1550} 4)Beil **1**, 379, (192), [413] & {1568} 5)P. Tavernier, MP **38**, 309(1956) 6)Sax(1957), 396,

397 & 793 7)CondChemDict(1961), 182,183 & 622 8)US Spec TT-B-00846A & TT-B-846(1) (n-Butanol for use in org coatings) 9)US Spec TT-B-848B(sec-Butanol for use in org coatings) 10)US Spec TT-I-730(iso-butanol for use in org coatings)

**Butanol Nitrate or Butyl Nitrate,** $C_4H_9NO_3$; mw 119.12, N 11.76%. Four isomers are known: *n-Butyl Nitrate,* $CH_3(CH_2)_2CH_2(ONO_2)$, col liq, bp 136°, fl p 97°F, d 1.03 at 20°(Refs 1,5 & 6); *sec-Butyl Nitrate,* $CH_3.CH_2.CH(ONO_2)$, liq, bp 124°, d 1.038 at 0°, vap d 4.0(Refs 2 & 5); *iso-Butyl Nitrate,* $(CH_3)_2CH.CH_2(ONO_2)$, liq, bp 123°, d 1.017 at 20°(Ref 3); and *tert-Butyl Nitrate,* $(CH_3)_3.C(ONO_2)$, liq, bp 21-2° at 4-5mm, d 1.015 at 20°(Refs 4 & 4a). These compds are formed by adding $HNO_3$ to the corresponding alcs. They are non-expl but form other derivs which are expl

*Refs:* 1)Beil **1**, 369, [397] & {1509} 2)Beil **1**, 372, (188) 3)Beil **1**, 377, [411] & {1562} 4)Beil **1**, {1582} 4a)A.Michael & G.H.Carlson, JACS **57**, 1271(1935) & CA **29**, 5811(1935) 5)Sax(1957), 408-9 6)CondChemDict(1961), 188

**Nitrobutanol Nitrate or Nitrobutyl Nitrate,** $C_4H_8N_2O_5$; mw 164.12, N 17.07%. Several isomers are known: *2-Nitro-1-butyl Nitrate,* $CH_3{\cdot}CH_2{\cdot}CH(NO_2){\cdot}CH_2(ONO_2)$, liq, d 1.242 at 15.5°(Ref 1); *2-Nitro-3-butyl-nitrate,* $CH_3{\cdot}CH(ONO_2){\cdot}CH(NO_2){\cdot}CH_3$, no props given(Ref 3); *Nitro-iso-butyl Nitrate,* $O_2N.CH_2.CH(CH_3).CH_2(ONO_2)$, was used as a sensitizer, together with AN & other substances, to form a safety expl(Ref 3); and *Nitro-tert-butyl Nitrate* or *1-Nitro-2-methyl-2-propyl Nitrate.* $(CH_3)_2C(ONO_2).CH_2.NO_2$, liq, bp 78° at 1mm, fr p 6°, d 1.283 at 20°, $n_D$ 1.449 at 20°(Refs 1a,3,4,5,6,7 & 8); can be used as a monofuel in the presence of a catalyst(Ref 7), the IR spectra of these compds are given in Brown(Ref 8)

*Refs:* 1)Beil **1**, 370 1a)Beil **1**, {1588} 2)R.F.B. Cox, USP 2330112(1943) & CA **38**, 1368(1944) 3)A.E.Wilder-Smith et al, BritP 580260(1946) & CA **41**, 2069(1947) 4)A.E.Wilder-Smith et al, BritP 586022(1947) & CA **41**, 6893(1947) 5)N. Levy et al, JCS **1948**,53,57 & CA **42**, 4906(1948) 6)A.E.Wilder-Smith et al, USP 2453942(1948) & CA **43**, 5411(1949) 7)A.C.Hutchison, "The Use of Alkyl Nitrates as Liquid Monofuels", ICIL, Nobel Div(1950),p 8 8)J.F.Brown, Jr, JACS **77**, 6341-51(1955) & CA **50**, 2297(1956)

**Butanol Nitrite or Butyl Nitrite,** $C_4H_9NO_2$; mw 103.12, N 13.58%. The following isomers are known: *n-Butyl Nitrite* $CH_3(CH_2)_2CH_2)ONO)$, liq, bp 77.8°, d 0.876 at 26°, vap d 3.5(Refs 1 & 7); *sec-Butyl Nitrite,* $CH_3.CH_2$-$CH(ONO)CH_3$, liq, bp 68°, d 0.898 at 0°, vap d 3.5(Refs 2 & 7); *iso-Butyl Nitrite* $(CH_3)_2CH.CH_2(ONO)$, liq, bp 67.1°, d 0.865 at 25°, $n_D$ 1.3715 at 22.1°(Ref 3); and *tert-Butyl Nitrite,* $(CH_3)_3C(ONO)$, yel liq, bp 68°, d 0.894 at 0°, vap d 3.5(Refs 4 & 7). Other props & methods of prepn are given in the Refs. Butyl nitrite is a fuel & is the most ignitable of the fuels examined by Mullins(Ref 6)

*Refs:* 1)Beil **1**, 369, [397] & {1509} 2)Beil **1**, 372 & [402,404,405] 3)Beil **1**, 377, (190), [411] & {1562} 4)Beil **1**, 382, [415] & {1582} 5)W.A.Noyes, OrgSynth Coll Vol **2** (1943),pp 108-9(Prepn of butyl nitrite) 6)B.P. Mullins, Fuel **32**, 451-66(1953) & CA **47**, 12785-6(1953) 7)Sax(1957), 409

**Nitrobutanol Nitrite or Nitrobutyl Nitrite,** $C_4H_8N_2O_4$; mw 148.12, N 18.91%. Two isomers are described in the literature: *4-Nitro-1-butyl Nitrite,* $O_2N.CH_2(CH_2)_2CH_2(ONO)$, liq, bp 110° at 14mm (dec)(Refs 1 & 2); and *Nitro-tert-butyl Nitrite or 1-Nitro-2-methyl-2-propyl Nitrite,* $(CH_3)_2C(ONO)CH_2.NO_2$, oily liq, fr p 24.5-25.5°, bp 82-3° at 1mm, d 1.302 at 25°, $n_D$ 1.4599 at 25°(Ref 3). Other props & methods of prepn are given in the Refs

*Refs:* 1)Beil **1**, (187) 2)J.vonBraun & W. Sobecki, Ber **44**, 2528(1911) & JCS **100 I**, 830 (1911) 3)C.C.Price & C.A.Sears, JACS **75**, 3276(1953) & CA **49**, 6153(1955)

**Mononitrobutanol,** $C_4H_9NO_3$; mw 119.12, N 11.76%. The following are among the known isomers: *2-Nitrobutan-1-ol,* $CH_3.CH_2.CH(NO_2).CH_2.OH$, liq, fr p -47°, bp 127-30° at 35mm, d 1.137 at 11.5°(Refs 1 & 7); *4-Nitrobutan-2-ol,* $O_2N(CH_2)_4OH$, liq, bp 103° at 2mm, d 1.112 at 20°(Ref 6); *1-Nitrobutan-2-ol,* $CH_3.CH_2.CH(OH).CH_2.NO_2$, viscous liq, bp 123-25° at 35mm(dec), d 1.191 at 18°(Ref 2); *3-Nitrobutan-2-ol,* $CH_3.CH(NO_2).CH(OH).CH_3$, liq, bp 112-13° at 38mm, d 1.116 at 7.8°(Ref 3); *β-Nitro-iso-butanol or 2-Nitro-2-methyl-1-propanol,* $(CH_3)_2C(NO_2)CH_2.OH$, ndls or lfts(from MeOH), mp 82°(Ref 4); and *Nitro-tert-butanol,* $(CH_3)_2C(OH)CH_2.NO_2$, ndls, mp 26°, bp 66° at 1mm, d 1.132 at 20°(Refs 5 & 5a). Other props & methods of prepn are given in the Refs

*Refs:* 1)Beil **1**, 370 & {1519} 2)Beil **1**, 373, [403] & {1546} 3)Beil **1**, 373 & {547} 4)Beil **1**, 378 & {1564} 5)Beil **1**, {1588} 5a)N.Levy

et al, JCS **1948**, 53, 57 & CA **42**, 4906(1948) 6)H.Shechter et al, JACS **74**, 3667(1952) & CA **47**, 5886(1953) 7)Sax(1957, 946

**Dinitrobutanol**, $C_4H_8N_2O_5$; mw 164.12, N 17.07%. Several isomers are known: *2,2-Dinitrobutan-1-ol*, $CH_3.CH_2C(NO_2)_2.CH_2.OH$, pale-yel liq, fr p -5°; was prepd by reaction of an aq soln of the K salt of 1,1-dinitropropane & formaldehyde. It is a powerful expl having the following props(Ref 3): *Explosion Temperature*, does not expl up to 360°; *Hygroscopicity* at 25°, gains 0.82% at 100%RH; *Impact Sensitivity*, ca the same as TNT; *Power* by Ballistic Mortar Test 94%TNT, using a Tetryl booster; *Reactivity*, cleaved to 1,1-dinitropropane & HCHO by $K_2CO_3$; and *Stability* by 135°Heat Test, acid in 30min, no expl in 300min & by 75°International Test, looses 1.6%; and *1,1-Dinitrobutan-2-ol*, $CH_3.CH_2.CH(OH)CH(NO_2)_2$, oily liq, diffc sol in w; was prepd by the action of the K salt of dinitromethane & propionaldehyde in water. Its *K salt*, $K.C_4H_7N_2O_5$, yel lfts, explodes ca 205°(Ref 1); *3,3-Dinitrobutan-2-ol*, $CH_3.CH_2.C(NO_2)_2.CH(OH).CH_3$, described in Conf Ref 5; *1,1-Dinitro-butan-3-ol*, $CH_3.CH(OH).CH_2.CH(NO_2)_2$, a new compd, prepn & proof of structure to be published (Ref 6); and *1,3-Dinitro-tert-butanol or 1,3-Dinitro-2-methylpropan-2-ol*, $O_2N.CH_2.C(CH_3)(OH).CH_2.NO_2$, col crysts, mp 31°, fr p 108° at <1mm; was prepd by reaction of 3-nitro-2-methyl-1-propylene with $N_2O_4$ in eth at -10° and treating the reaction product with water(Refs 2 & 4). The IR spectra of various nitro & other oxidized nitro compds are given by Brown(Ref 6). The dinitro compds of butanol are expl

*Refs:* 1)Beil **1**, 373 2)Beil **1**, {1589} 3)Blatt, OSRD **2014**(1944) 4)N.Levy et al, JCS **1948**, 58 & CA **42**, 4906(1948) 5)Aerojet Rept **331**(1948),pp 69 & 143(Confidential) 6)J.F.Brown, Jr, JACS **77**, 6342-45(1955) & CA **50**, 2297(1956)

**1,1,1-Trinitrobutanol**, $H_3C.CH_2.CH(OH).C(NO_2)_2$. The prepn of this compd from propionaldehyde & nitroform was reported in Ref 2. Later it found(Ref 3), that the compd was actually *methyl-1,1,1-trinitro-2-butyl ether*, $H_3C.CH_2.CH(O.CH_3).C(NO_2)_3$

*Refs:* 1)Beil-not found 2)US Rubber Co Quarterly Progress Rept No 2, Contract Nord **10129**, Passaic, NJ(1948-49), 17-18 3)Ibid, Rept No 9(1949-50), 7-8

**1-Butanol-2-amine.** See 2-Amino-1-butanol; Vol 1,p A192-L

**Butanolaniline.** See Anilinobutanol; Vol 1,p A422-R

### Butanone and Derivatives

*Butanone or Methylethylketone*(called Butanon or Methyläthylketon in Ger), $CH_3.CH_2.CO.CH_3$; mw 72.10, O 22.9%; col, flammable liq having acetone-like odor, fr p -86°, bp 79°, flash p 22°F(TOC), d 0.8062 at 20°, vap d 2.41, vap press 71.2mm at 20°, $n_D$ 1.379 at 20°; sol in alc, eth or w & miscible with oils. Sax(Ref 4) lists its MAC as 250 ppm or 735mg/m³ in air and its expl range 1.81 to 11.5%. Smith & Mayers(Ref 2) reported that acute poisoning was produced from a combination of acetone & butanone vapors in a concn of 1000 ppm. Low-grade intoxication & dermatitus were caused by butanone alone in concns of 300-600 ppm. Prepn & other props of butanone are given in the Refs. It is used as a solvent, in org synthesis & in the manuf of smokeless proplnts

*Refs:* 1)Beil **1**, 666, (347), [726] & {2770} 2)A.E.Smith & M.R.Mayers, IndBull(NY State Dept of Labor) **23**, 174-6(1944) & CA **38**, 5613 (1944) 3)Shell Chemical Corp, "Methyl Ethyl Ketone", NY(1950), 129pp [Reviewed in JChemEd **27**, 696(1950)] 4)Sax(1957), 392 5)Faith, Keyes & Clark(1957), 517-19 6)Cond-ChemDict(1961), 739

**Azidobutanone or Butanone Azide**, $C_4H_7N_3O$; mw 113.12, N 37.15%. Two isomers are known: *1-Azidobutan-2-one*, $CH_3.CH_2.CO.CH_2.N_3$, col oil, bp 56° at 2mm, d 1.084 at 18°; ignites with a feeble deton when thrown on a hot plate; was prepd by treating 1-chlorobutan-2-one with aq $NaN_3$ contg a little acetic acid(Refs 1 & 2,p 677); and *3-Azidobutan-2-one*, $CH_3.CH(N_3).CO.CH_3$, col oil, bp 46° at 2mm, d 1.057; vaporizes w/o ign or deton when dropped on a hot plate; was prepd from 1-chlorobutan-2-one, aq $NaN_3$ & a little acetic acid(Refs 1 & 2,p 675)

*Refs:* 1)Beil **1**, 671 2)M.O.Forster & H.E. Fierz, JCS **93** I, 675 & 677(1908)

**3-Diazobutan-2-one**, $CH_3.C(:N\overset{+}{:}N).CO.CH_3$; mw 98.10, N 28.56%; dk-orn liq having a stupefying ethereal odor, bp 45° at 12mm; the olive-grn vapor explodes violently when air is admitted too quickly to the distilling flask; was prepd by treating diacetyl monohydrazone in abs eth with silver oxide & sodium sulfate; it evolves N when treated with w, alc or acids(Refs 1 & 2). See also Ref 3

*Refs:* 1)Beil **1**, (399) 2)O.Diels & K.Pflaumer, Ber **48**, 229(1915) & JCS **108** I, 128(1915) 3)B.

Prijs et al, Helv **30**, 2112(1947) & CA **42**, 1934 (1948)

**Mononitrobutanone**, $C_4H_7NO_3$; mw 117.10, N 11.96%. Two isomers are described in the literature: *1-Nitrobutan-2-one*, $CH_3.CH_2.CO.CH_2.NO_2$, liq, fr p 12-15°, bp 92-100° at 8mm & 118° at 28mm, d 1.156 at 20°, $n_D$ 1.4410 at 20°; and *3-Nitrobutan-2-one*, $CH_3.CH(NO_2).CO.CH_3$, col liq, fr p- failed to solidify in ice-salt, bp 71-5° at 9mm & 92° at 25mm, d 1.156 at 20°, $n_D$ 1.4349 at 20°. These nitroketones were synthetized by oxidn of the corresponding alcohols. The nitrobutanones must be distilled at reduced pressure, with air excluded, in order to prevent violent decompn. The Na salts as well as the bromo derivs of these nitrobutanones were prepd

*Refs:* 1)Beil-not found 2)C.D.Hurd & M.E. Neilson, JOC **20**, 932(1955) & CA **50**, 6310(1956)

**Butanone Azide.** See Azidobutanone

### Butanoneoxime and Derivatives

*Butanoneoxime* [called Butanoxim-(2) or Methyläthylketoxim in Ger], $CH_3.CH_2.C(:NOH).CH_3$; mw 87.12, N 16.08%; col oil, fr p -29.5°, bp 151-2°, d 0.9232 at 20°, $n_D$ 1.4410 at 20°. Other props & methods of prepn are given in the Ref

*Ref:* Beil **1**, 668, (348), [730] & {2784}

*1-Azidobutanone-2-oxime*, $CH_3.CH_2.C(:N.OH).CH_2.N_3$: mw 128.14, N 43.73%; liq, obtd by treating 1-azidobutan-2-one with aq hydroxylamine; decompd by warming with dil alk & yielded $HN_3$ when acidified(Refs 1 & 2)

The *p-Toluenesulfonyl deriv*, $C_{11}H_{14}N_4O_3S$, col ndls(from petr), mp 72°, obtd by mixing the oxime in pyridine soln with the calcd quantity of p-toluenesulfonyl chloride, exploded when heated at or above its mp(Ref 2)

*Refs:* 1)Beil **1**, 671 2)M.O.Forster & H.E. Fierz, JCS **93** I, 678(1908)

**Butanone Peroxide Dimer, Methylethylketone Peroxide**, $(C_4H_8O_2)_2$; mw 176.21, O 36.20%; col thick oil, having a pleasant odor; stable at RT but explodes when heated above 100°, d 1.042; was obtd when butanone was treated with $H_2O_2$ in the presence of $H_2SO_4$; sol in alc, eth or benz; insol in w. The compd is completely reduced to methylethylketone by the action of nascent H in the cold; it explodes violently when placed in contact with concd $H_2SO_4$. Butanone peroxide is sold under the trade name "Lupersol DDM", by Wallace & Tiernen, Inc, Buffalo, NY(Ref 3)

*Refs:* 1)Beil **1**, 668 2)J.Pastureau, CR **144**, 91(1907); CA **1**, 1121(1907) & JCS **92** I, 185(1907) 3)CondChemDict(1961),p 683

### Butene and Derivatives

**Butene or Butylene**(called Buten or Butylen in Ger), $C_4H_8$, mw 56.10. Four isomers exist: *1- or α-Butene*, $CH_2:CH.CH_2.CH_3$, gas, fr p -185°, bp -6.3, flash p -80°, d 0.5951 at 20°, vap d 1.93(Ref 1; 4,p 404 & 5,p 179); *cis-2 or β-Butene*, $CH_3.CH:CH.CH_3$, gas, fr p -139°, bp 3.7°, flash p -73°, d 0.6213 at 20°, vap press 1410mm at 21°(Ref 2; Ref 4,p 393 & Ref 5,p 180); *trans-2 or β-Butene*, gas, fr p -105.8°, bp 0.9°, flash p -73°, d 0.6042 at 20°, vap press 1592mm at 21°(Refs 2; Ref 4,p 393 & Ref 5,p 180); and *iso-Butene, iso-Butylene or 2-Methylpropene*, $(CH_3)_2C:CH_2$, vol liq or easily liquified gas, fr p -139°, bp -6.9°, flash p -76°, d 0.600 at 20°, vap press 3290mm at 40.5°(Ref 3; Ref 4,p 795 & Ref 5,p 621). The toxicity details of these compds are unknown but they act as anesthetic or asphyxiant(Ref 4). Prepn & other props of these compds are given in Beil(Refs 1,2 & 3). They are used as solvs, in org synthesis as intermediates & as starting materials for liq fuels(Ref 4)

*Note:* When 5g of iso-butylene was treated with 1.9g of nitroform in 7ml of ether(as described in Ref 3a), there was obtained 1.2g of liquid which could not be purified by distillation even at 1 micron pressure. Its probable compn was: $2[(CH_3)_2C:CH_2] + HC(NO_2)_3$. An attempt to prep a larger quantity resulted in a violent expln. This reaction has not been investigated further

*Refs:* 1)Beil **1**, 203, (84) & [173] 2)Beil **1**, 204, (85) & [175] 3)Beil **1**, (85) & [179] 3a)US Rubber Co, Quarterly Progress Rept N5, Contract Nord **10129**, Passaic, NJ(1949-50), 10 4)Sax(1957), 393, 404 & 795 5)CondChemDict (1961), 179, 180 & 621

**Mononitrobutene**, $C_4H_7NO_2$; mw 101.10, N 13.86%. The following isomers are known: *1-Nitro-1-butene*, $CH_3.CH_2.CH:CH.NO_2$, yel liq having a pungent odor, bp 55° at 12mm, d 1.025 at 20°, $n_D$ 1.4532 at 20°(Refs 2 & 3); *2-Nitro-1-butene*, $CH_3.CH_2C(NO_2):CH_2$, liq, bp 60.5° at 50mm(Refs 4 & 8), volatility & vap press are given by Redemann et al(Ref 6); during the prepn of polynitro paraffins, Bahner & Kite (Ref 7) found that metallic Na added to an equi-molar mixt of $(CH_3)_2CH.NO_2$ & 2-nitro-1-butene at 8° caused a violent reaction & mild expln; *1-Nitro-2-butene(trans)*, $CH_3.CH:CH.$-

$CH_2NO_2$(Ref 9); *2-Nitro-2-butene,* $CH_3.CH:C(NO_2).CH_3$, bp 58° at 18mm & 70.4° at 30mm, d 1.043 at 25°, $n_D$ 1.4584 at 25°(Refs 5 & 8); *α-Nitro-iso-butene or 1-Nitro-2-methyl-1-propene,* $(CH_3)_2C:CH.NO_2$, lt yel oil having a disagreeable odor, bp 154-8°(partial decompn), d 1.052 at 0° (Refs 1) and *1-Nitro-2-methyl-2-propene or 3-Nitro-2-methyl-1-propene,* $CH_2:C(CH_3).CH_2.NO_2$, props not given(Ref 9). The IR spectra of the above compds, except 2-nitro-1-butene & 2-nitro-2-butene, are given by Brown, Jr(Ref 9). Methods of prepn & other props are given in the Refs

*Refs:* 1)Beil 1, 209 2)Beil 1, [175] 3)E. Schmidt & G.Rutz, Ber **61**, 2147(1928) & CA **23**, 372(1929) 4)Visking Corp, BritP 593109(1947) & CA **44**, 653(1950) 5)N.Levy et al, JCS **1948**, 5260 & CA **42**, 4906(1948) 6)C.E.Redemann et al, JACS **70**, 2582(1948) & CA **42**, 8563(1948) 7)C.T.Bahner & H.T.Kite, JACS **71**, 3597-8 (1949) & CA **44**, 1010(1950) 8)H.B.Haas et al, JOC **15**, 8(1950) & CA **44**, 4412(1950) 9)J.F. Brown, Jr, JACS **77**, 6342(1955) & CA **50**, 2297(1956)

**Dinitrobutene,** $C_4H_6N_2O_4$; mw 146.10, N 19.18%. The following isomers exist: *3,3-Dinitro-1-butene,* $CH_3.C(NO_2)_2.CH:CH_2$, liq, bp 59.0-59.5° at 4.5mm, d 1.248 at 20°, $n_D$ 1.4535 at 20°; was prepd from 3,3-dinitro-1-bromobutane & NaOMe in methyl alcohol(Ref 4); *1,4-Dinitro-2-butene,* $O_2N.CH_2.CH:CH.CH_2.NO_2$, yel oil , bp 58-60(dec); was prepd by the action of $NO_2$ or $N_2O_4$ on butadiene(Refs 2 & 5); was proposed as an insecticide & as a solvent for NC(Ref 2; and *2,3-Dinitro-2-butene,* $CH_3.C(NO_2):C(NO_2).CH_3$, pale yel liq, fr p 28-9°, bp 96-8° at 1mm (sublimes at 20° & $10^{-4}$ mm); IR spectra indicate trans form(Ref 6); was prepd by the action of $N_2O_4$ on butyne-2($CH_3.C{\equiv}C.CH_3$) in acet under cooling(Ref 6); was considered suitable as an ign improving agent in diesel fuels & as an intermed in org synthesis(Ref 3)

*Refs:* 1)Beil-not found 2)R.G.Franklin & F.J. Wilkins, USP 2314615(1943) & CA **37**, 5188 (1943) 3)E.M.Nygaard & T.T.Noland, USP 2396282(1946) & CA **40**, 3126(1946) 4)H. Shechter & L.Zeldin, JACS **73**, 1276(1951) & CA **45**, 9458-9(1951) 5)C.R.Porter & B.Wood, JInstPetroleum **38**, 877(1952) & CA **47**, 10457 (1953) 6)H.H.Schlubach & W.Rott, Ann **594**, 59-66(1955) & CA **50**, 10666(1956)

**Trinitrobutene,** $C_4H_5N_3O_6$; mw 191.10, N 21.99%. The *4,4,4-Trinitro-1-butene,* $(O_2N)_3C.CH_2.CH:CH_2$, is described in Conf Aerojet Rpt **331**(1948), pp 68 & 143

**Butene Polymer Dynamite.** A cohesive, nonsifting Dynamite was prepd from NG 6, AN 80.4, $NaNO_3$ 5, woodpulp 2, fine apricot-pit pulp 4.1, yel corn flour 1.5, chalk 0.5 & 0.5% of a soln contg 7.5% polybutene(solid rubber of mw 80,000) in liq polybutene(viscosity 154 Saybolt Universal seconds at 210°F)(Ref). Other formulations of powdery cohesive Dynamites are also given

*Ref:* W.J.Taylor, USP 2541389(1951) & CA **45**, 4930(1951)

**Butenoic Acid.** Same as Crotonic Acid

**Butenyl.** The monovalent radical $C_4H_7$- derived from butylene or butene

**Butine or Butyne.** An unsaturated hydrocarbon contg a triple bond

**Butlerov, Alexander M.**(1828-1886). Russian chemist known for his numerous works in organic chemistry. He discovered formaldehyde in 1859 and studied its reactions with ammonia, including the formation of hexamethylenetetramine

*Refs:* 1)H.M.Leicester, JChemEduc **17**, 203-9 (1940) 2)Walker, Formaldehyde(1953), 2

**Butterfly Bombs.** See Bombs, Butterfly under List of Bombs

**Butterfly Valve.** See under Cartridge Actuated Devices

**Butt Target.** A mound, bank or other backstop of earth that catches bullets & projectiles from artillery or rifles used in target practice or proving ground tests

*Ref:* Merriam-Webster's(1961), 304

**iso-Butyl Acetyl Ricinoleate**(called Acetat des Ricinolsäureisobutylesters in Ger), $C_{24}H_{44}O$, mw 396.59; non-vol liq, bp 255-60° at 13mm, d 0.9012 at 22°, $n_D$ 1.4548 at 22°; was prepd from iso-butyl ricinoleate and acetyl chloride at 60-80°(Ref 1)

This non-expl compd was proposed as a surface gelatinizer for double-base propints used at sub-zero temps(Ref 2). It is a non-solv for NC, but is compatible in a mixt contg NC, NG, rosin & a solv(such as o-benzoylbenzoate) for NC; and may be suitable, therefore, as an ingredient

of certain proplnts
*Refs:* 1)Beil **3**, 388 2)E.S.Goodyear, USP 2179330(1939) & CA **34**, 1488(1940)

**Butyl Alcohol.** See Butanol

### Butylamine and Derivatives

*Butylamine or Aminobutane*, $C_4H_9NH_2$. Several isomers are known and described in Beil **4**,156, 160,161,173,(370,372,376) & [631,636 & 641]

**Butylnitramine**, $C_4H_{10}N_2O_2$; mw 118.14, N 23.71%. Three isomers are described in the literature: *n-Butylnitramine*, $C_4H_9.NH.NO_2$, liq, fr p -1 to 0°, bp 123-5° at 20mm, d 1.058 at 23°, $n_D$ 1.4603 at 25°; forms several cryst salts (Ref 1 & 2). Smart & Wright(Ref 3) prepd the compd by nitration of n-butyldichloramine(1 mol) in acetic anhydride(5 mols) with 98% $HNO_3$ (3 mols). When the nitration was attempted in 10 equivalents of $HNO_3$ and w/o acetic anhydride, the reaction mixt survived at-35° but decompd explosively when warmed to -20°; *sec -Butylnitramine*, $C_2H_5.CH(CH_3).NH.NO_2$, liq, fr p -32.5°, bp 106.2-106.7° at 15mm, d 1.057 at 22°, $n_D$ 1.4572 at 25°(Refs 1 & 2). Smart & Wright(Ref 3) prepd the compd by nitration of sec-butyldichloramine in sl more that equiv amts of acet anhyd & $HNO_3$. The intermediate compd, sec-Butyl-N-chloronitramine could not be isolated because of its expl nature; but a compd believed to be sec-Butylnitramine, $C_2H_5.C(CH_3):N.NO_2$, was isolated; *iso-Butylnitramine*, $(CH_3)_2.CH.CH_2.NH.NO_2$, cryst, mp 32.2°, d 1.142 at 15°; forms crysts salts(Ref 1); other props & method of prepn are given in Ref 2
*Refs:* 1)Beil **4**, 571(569) 2)H.Van Erp, Rec **14**,26,31,32(1895) 3)G.N.R.Smart & G.F.Wright, CanJRes **26B**,290,291(1948) & CA **42**, 5844 (1948)

**Butylaminobenzene.** Same as Butylaniline

**1-Butylaminobenzene-4-diazonium Hydroxide**, $C_4H_9.NH.C_6H_4.N(:N).OH$; mw 193.24, N 21.75%; known only in the form of its salts, some of which are expl; *Platinic Chloride* salt, $(C_{10}H_{14}N.N_2.Cl)_2 + PtCl_4$, yel ppt, turns dark at 115-20°, dec at 147-50° and explodes on heating in a flame; sl sol in alc, almost insol in w; was prepd by treating a soln of platinic chloride with the diazotized aq soln of butylaminodiazonium dihydrochloride, which was obtd by reacting N-butylphenylene diamine with $NaNO_2$ & HCl
*Refs:* 1)Beil **16**, (371) 2)J.Reilly & W.J. Hickinbottom, JCS **111**, 1034(1917)

**Butylaminoethanol.** Same as Butylethanolamine

**Butylaminomethylbenzene.** Same as C-Butylaminotoluene

### C-Butyl-aminotoluene and Derivatives

*C-Butyl-aminotoluene, C-Butyl-methylaniline or C-Butylaminomethylbenzene*(called Aminomethylbutylbenzol in Beil), $C_4H_9.C_6H_3(NH_2).CH_3$. Six isomers are described in Beil **12**, 1180 & [643,645]

*Nitro-C-butyl-aminotoluene*, $C_4H_9.C_6H_2(NO_2)(NH_2).CH_3$. One isomer is described in Beil **12**, 1181

*Dinitro-C-butyl-aminotoluene*, $C_4H_9.C_6H(NO_2)_2(NH_2).CH_3$. One isomer is described in Beil **12**, 1181

**Trinitro-C-butyl-aminotoluene**, $C_{11}H_{14}N_4O_6$, mw 298.25, N 18.79%. One isomer, *3,5,6-Trinitro-4-(tert-butyl)-1-amino-toluene or 3,5,6-Trinitro-4-(tert-butyl)-2-methyl-aniline*, [called 2.4.5-Trinitro-6-amino-1-methyl-3-(tert -butyl)-bnzol in Ger], $C_4H_9.C_6(NO_2)_3(NH_2).CH_3$, crysts(from alc), mp 168°; was prepd by diazotizing an alc soln of 5-nitro-4 -(tert-butyl)-1-amino-toluene, followed by distn with steam. Energetic nitration of the trinitro deriv yielded an acid expl product; yel ndls(from alc), mp 224° of assumed formula, $C_6(NO_2)_5.NH.NO$
*Refs:* 1)Beil **12**, 1181 2)A.Baur, Ber **30**, 304-5 (1897) & JCS **72** I, 216(1897)

### N-Butyl-aminotoluene and Derivatives

*N-Butyl-aminotoluene; N-Butyl-methylaniline; N-Butyl-toluidine*, $C_4H_9.HN.C_6H_4.CH_3$. Four isomers are described in Beil **12**, (377,414) & [436,492]

*Nitro-N-butylaminotoluene*, $C_4H_9.NH.C_6H_3(NO_2).CH_3$. Three isomers are described in Beil **12**, (438, 440)

*3,5-Dinitro-4-N-butyl-aminotoluene*, $C_4H_9.HN.C_6H_2(NO_2)_2.CH_3$; mw 253.25, N 16.59%; orn-red ndls, mp 53-4°, is described in Beil **12**,(443)

*3,5-Dinitro-4-(N-butyl-N-nitroso)-aminotoluene*, $C_4H_9.N(NO).C_6H_2(NO_2)_2.CH_3$; mw 282.25, N 19.85%, lt yel plates, mp 56-7°, is described in Beil **12**,(444)

*3,5-Dinitro-4-(N-butyl-N-nitro)-aminotoluene*, $C_4H_9.N(NO_2).C_6H_2(NO_2)_2.CH_3$, mw 298.25,

N 18.97%, yel ndls, mp 95°, is described in Beil **12**, (444)

**2,3,5-Trinitro-4-(N-butyl-N-nitroso)-aminotoluene,** $C_4H_9.N(NO).C_6H(NO_2)_3.CH_3$, mw 327.25, N 21.40%, yel crysts(from dil alc), mp 80.5°. Can be prepd by treating(at 30-35° for 2 hrs) 2-nitro-N-butylaminotoluene sulfate with a mixt of $HNO_3$(d 1.4) and concd $H_2SO_4$. Its expl props were not investigated

*Refs:* 1)Beil **12**, (445) 2)J.Reilly & W.J. Hickinbottom, JCS **113**, 993(1918)

**2,3,5-Trinitro-4-(N-butyl-N-nitro)-aminotoluene,** $C_4H_9.N(NO_2).C_6H(NO_2)_3.CH_3$, mw 343.25, N 20.40%, crysts(from $HNO_3$), mp 87-8°; easily sol in benz, chlf or boiling methanol or ethanol; sl sol in cold methanol. Can be prepared either by crystn of the corresponding nitrosamine from $HNO_3$ or by nitration of 2-nitro-N-butylamino-toluene with $HNO_3$(d 1.5) as described in Ref 2. Its expl props were not investigated

*Refs:* 1)Beil **12**, (445) 2)J.Reilly & W.J. Hickinbottom, JCS **113**, 993(1918)

**Butylammonium Tetrazidocuprate,** $(C_4H_9.NH_3)_2$-$[Cu(N_3)_4]$, mw 379.92, N 51.62%. Two isomers are known: *n-Butyl salt,* expl at 178-80° and *iso-Butyl salt,* mp 125°, expl at 203°; both compds expl also under impact. These and other complex salts of cupric azide, $[Cu(N_3)_2]$, were prepd & studied by Straumanis & Cirulis(Ref 2) and by others. See also Cupric Azide Complexes; Vol 1, p A533-R

*Refs:* 1)Beil-not found 2)M.Straumanis & A. Cirulis, ZAnorgChem **252**, 9-23(1943) & CA **38**, 3564(1944)

### C-Butyl-aniline and Derivatives

*C-Butyl-aniline, C-Butyl-aminobenzene or Aminobutylbenzene,* $C_4H_9.C_6H_4.NH_2$, mw 149.23, N 9.39%. Six isomers are described in Beil **12**, 1166, (503,505) & [633,636 & 637]

*Monoitro-C-butyl-aniline,* $C_4H_9.C_6H_3(NO_2.NH_2$, mw 194.23, N 14.42%. Five isomers are described in Beil **12**,1166,1169 & [634,637]

**Dinitro-C-butyl-aniline, C-butyl-aniline,** $C_4H_9.C_6H_2(NO_2)_2.NH_2$, mw 239.23, N 17.57%. One isomer, *2,6-Dinitro-4-(tert-butyl)-aniline,* $(CH_3)_3C.C_6H_2(NO_2)_2.NH_2$, yel crysts, mp 127°, is described in Beil **12**, 1169

*Trinitro-C-butyl-aniline,* $C_4H_9.C_6H(NO_2)_3.NH_2$, mw 284.23, N 19.71%. Not found in Beil or CA through 1960

### N-Butylaniline and Derivatives

**N-Butylaniline, N-Butylaminobenzene or Phenylbutylamine**(called Butylanilin in Ger), $C_{10}H_{15}N$, mw 149.23, N 9.39%. Four isomers exist and are described in the literature: *n-Butylaniline,* $CH_3.(CH_2)_3.NH.C_6H_5$, col liq, fr p -15.1°, bp 241°, flash p 225°F(COC)(Refs 1, 4 & 5); *sec-Butylaniline,* $C_2H_5.CH(CH_3).NH.C_6H_5$; aromatic oil, having pleasant odor, bp 224-5° at 765mm(Ref 3); *iso-Butylamine,* $(CH_3)_2CH.CH_2.NH.C_6H_5$, oil, bp 225-7°, d 0.940 at 18°(Refs 2 & 3); and *tert-Butylaniline,* $(CH_3)_3C.NH.C_6H_5$, oil, bp 208-10°(Ref 2). These isomers form crysts salts, some of which are unstable when heated. Other props & methods of prepn are given in the Refs

*Refs:* 1)Beil **12**, 168,(160) & [95] 2)Beil **12**, 168 3)Beil **12**, [96] 4)Sax(1957), 398 5) CondChemDict(1961), 183

**N-Nitroso-N-butylaniline,** $C_{10}H_{14}N_2O$; mw 178.23, N 15.75%. Two isomers are described in the literature: [*N-Nitroso-N-(n-butyl)*]-*aniline,* $CH_3.(CH_2)_3.N(NO).C_6H_5$, grn-yel liq, vol in steam; sol in alc or eth; v sl sol in hot w(Ref 1); described by Fierz-David et al (Ref 3) as a reddish-brn oil, bp 132° at 13mm; and [*N-Nitroso-N(sec-butyl)*]-*aniline,* $C_2H_5.CH(CH_3).N(NO).C_6H_5$, yel aromatic oil, vol in steam(Ref 2). Other props & methods of prepn are given in the Refs

*Refs:* 1)Beil **12**, 580, (294) 2)Beil **12**, [310] 3)H.E.Fierz-David et al, Helv **29**, 1775(1946) & CA **41**, 2411(1947)

**Mononitro-N-butylaniline,** $C_4H_9.NH.C_6H_4.NO_2$; mw 194.23, N 14.42%. Two isomers are described in the literature: [*2-Nitro-N-(n-butyl)*]-*aniline,* crysts, mp 31-2°; and [*4-Nitro-N-(n-butyl)*]-*aniline,* crysts, mp 54°. These compds were prepd in excellent yields by heating 2- or 4-nitrofluorobenzene with n-butylamine in w with $Na_2CO_3$, $K_2CO_3$ or magnesia

*Refs:* 1)Beil-not found 2)R.L.Lantz & P. Obellianne, BullFr **1956**, 311-17 & CA **50**, 15444(1956)

**Dinitro-N-butylaniline,** $C_4H_9.NH.C_6H_3(NO_2)_2$; mw 239.23, N 17.57%. The following isomers exist: [*2,4-Dinitro-N-(n-butyl)*]-*aniline,* $CH_3.(CH_2)_3.NH.C_6H_3(NO_2)_2$, yel ndls(from alc or petr eth), mp 90-3°; readily sol in chlf, benz, alc, eth, acet, AcOH & $Ac_2O$; sol in petr eth & $CS_2$; was prepd by heating 2,4-dinitro-chlorobenzene with n-butylamine & alc at 100°(Refs 2, 4 & 6); [*3,5-Dinitro-N-(n-butyl)*]-*aniline,* yel plates, mp 99°; was separated by

partition chromatography from a mixt of secondary amines, obtd by heating 3,5 -dinitroaniline hydrobromide with n-butyl alcohol in a sealed tube at 100°(Ref 7); [*2,4-Dinitro-N -(sec-butyl)*] *-aniline*, $C_2H_5.CH(CH_3).NH.C_6H_3(NO_2)_2$, yel crysts, mp 56°; was prepd by heating an alcoholic soln of 1-chloro-2,4 -dinitrobenzene with sec-butylamine at 100° for several hrs(Ref 5); [*2,4-Dinitro-N-(iso -butyl)*] *-aniline*, $(CH_3)_2.CH.CH_2.NH.C_6H_3(NO_2)_2$, yel monocl prisms(from $CS_2$), mp 80°, d 1.342 at 20°(Refs 1 & 3); and [*2,4-Dinitro-N -(tert-butyl)*] *-aniline*, $(CH_3)_3.C.NH.C_6H_3(NO_2)_2$, yel crysts(from dil alc), mp 119°; was prepd from 1-chloro-2,4-dinitrobenzene and tert -butylamine(Ref 8). The expl props of dinitro -N-butylamines were not investigated

*Refs:* 1)Beil **12**, 751 2)Beil **12**, [406] 3)P. van Romburgh, Rec **4**, 192(1885) 4)E.J. van der Kam, Rec **45**, 732(1926) & CA **21**, 404 (1927) 5)J.J.Blanksma & H.H.Schreinemachers, Rec **52**, 430(1933) & CA **27**, 5065(1933) 6)Davis (1943),p 183 7)J.C.Roberts & K.Selby,JCS **1949**, 2787 & CA **44**, 3922(1950) 8)O.L.Brady & F.R.Cropper,JCS **1950**,516 & CA **45**,8971(1951)

**Trinitro-N-butylaniline**, $C_4H_9.NH.C_6H_2(NO_2)_3$; mw 284.23, N 19.71%. The following isomers are known and described in the literature: [*2,4,6-Trinitro-N-(n-butyl)*] *-aniline; (2,4,6 -Trinitrophenylamino)-n-butane; (2,4,6 -Trinitrophenyl)-n-butylamine or N-(n-Butyl) -2,4,6-trinitroaniline*, $CH_3(CH_2)_3.NH.C_6H_2(NO_2)_3$, orn-yel nds(from petr eth), mp 80.5-81°; readily sol in benz or chlf; less sol in petr eth; was prepd by condensing picryl chloride with n-butylamine in alc(Refs 2 & 4); *2,4,6-* [*Trinitro-N-(sec-bytyl)*] *-aniline or N-(sec-Butyl)-2,4,6-Trinitroaniline*, $C_2H_5.CH(CH_3).NH.C_6H_2(NO_2)_3$, yel crysts, mp 78-80°; was prepd from DL-sec-butylamine (2 moles) and picryl chloride(1 mole) in alc; compd has only sl basic props; its HCl salt is decompd by w(Ref 5) and [*2,4,6-Trinitro-N -(iso-butyl)*] *-aniline or N-(iso-Butyl-2,4,6 -Trinitroaniline*, $(CH_3)_2CH.CH_2.NH.C_6H_3(NO_2)_3$, lt yel lfts(from acet or $CS_2$), mp 95°, d 1.445 at 18°; was prepd by reacting picryl chloride with iso-butylamine in alc soln(Refs 1 & 3). The expl props of these trinitro -butylanilines were not reported

*Note:* CA Formula Index 1920-1946, p 425, lists N-(tert-butyl)-picramide as being described in CA **26**, 2414. We could not find the compd in CA

*Refs:* 1)Beil **12**, 764 2)Beil **12**, (368) 3)P. van Romburgh, Rec **4**, 193(1885) 4)A.P.N. Franchimont, Rec **29**, 300(1910) 5)R.Weiss & A.Abeles, Monatsh **59**, 238(1932) & CA **26**, 2414(1932)

**Tetranitrobutylaniline**, $C_{10}H_{11}N_5O_8$; mw 329.23, N 21.27%. Two isomers are known: **[2,4,6-Trinitro-N-nitro-N-(n-butyl)] -aniline;** *sym-Trinitrophenyl-N-(n-butylnitramine); (2,4,6-Trinitrophenylnitramine)-n-butane or* **"Butyltetryl"**(called N-Nitro-N-butyl-N -2.4.6-trinitroaniline; N-Butyl-2.4.6 -tetranitroanilin or Butyl-pikryl-nitramin in Ger), $CH_3.(CH_2)_3.N(NO_2).C_6H_2(NO_2)_3$, lt yel lfts(from AcOH) or lemon yel plates(from alc); mp 98-100°; readily sol in benz, ethyl acet, alc or acet; insol in petr eth; was first prepd by Franchimont(Refs 2 & 4) from picrylchloride and the K salt of n-butylnitramine in warm alc and also by nitrating N-butyl-2,4,6 -trinitroaniline with absol $HNO_3$; Davis(Ref 6) prepd the compd by condensing 1-chloro-2,4 -dinitrobenzene with n-butylamine and nitrating the product and also by nitrating, in one step, n-butylaniline(See also Refs 5 & 7)

Butyltetryl is an expl comparable in power & brisance to TNT(97.5% TNT by Ballistic Mortar Test and the same as TNT by Sand Test); its sensitivity to impact is ca the same as that of Tetryl. It expl at 210° and is sl more sensitive to initiation that Tetryl(0.4g requires 0.19g MF vs 0.24g MF for 0.4g Tetryl). Butyltetryl was recommended for use in boosters, reinforced detonators, detonating fuse & priming caps(Refs 8, 9 & 10)

**[2,4,6-Trinitro-N-nitro-N-(iso-butyl)] -aniline** *or iso-Butyl-picryl-nitramine*(called N-Isobutyl-N.2.4.6-tetranitroanilin or N-Nitro -N-isobutyl-2.4.6-trinitroanilin in Ger), $(CH_3)_2CH.CH_2.N(NO_2).C_6H_2(NO_2)_3$, yel ndls (from alc), mp 110°; was prepd by nitrating either N-isobutyl-2,4-dinitroaniline or 2,4,6 -trinitroaniline with fuming $HNO_3$(Refs 1 & 3). It is an expl sl less powerful & brisant than TNT

*Refs:* 1)Beil **12**, 771 2)Beil **12**, (371) & [426] 3)P. van Romburgh, Rec **4**, 193(1885) 4)A.P.N. Franchimont,Rec **29**,301(1910) 5)J.Reilly & W.J.Hickinbottom, JCS **117**, 135(1920) & CA **14**, 1819(1920) 6)T.L.Davis, USP 1607059 (1926) & CA **21**, 325(1927) 7)M.S.Fishbein, VoennayaKhim **1933**, No 6, pp 3-8; ChemZtr **1934** II, 1074-5 & CA **29**, 7077(1935) 8)Davis (1943), 183 9)Blatt,OSRD **2014**(1944) 10) Pérez Ara(1945), 591

**Butylanisole and Derivatives**

*Butylanisole or Butylmethoxybenzene,* $C_4H_9.C_6H_4.O.CH_3$. Several derivs are described in Beil **6**, 522, (257) & [485]

**Dinitrobutylanisole or Dinitromethoxybenzene,** $C_4H_9.C_6H_2(NO_2)_2.O.CH_3$, mw 254.24, N 11.02%. One isomer *5-(tert-Butyl)-2,4-dinitroanisole,* yel ndls, mp 80-1°, is described in the literature. It is used for the prepn of trinitro compds

*Refs:* 1)Beil-not found 2)M.S.Carpenter et al, JOC **16**, 607(1951) & CA **46**, 1494(1952)

**Tinitrobutylanisole or Trinitrobutylmethoxybenzene,** $C_{11}H_{13}N_3O_7$; mw 299.24, N 14.04%. Two isomers are described in the literature: *3-(tert-Butyl)-2,4,6-trinitroanisole,* $(CH_3)_3C.C_6H(NO_2)_3.O.CH_3$, pale yel odorless ndls, (from methanol), mp 99.5-100°; was obtd, in addn to a little 5-(tert-butyl)-2,4-dinitroanisole, from the mother liq resulting from the nitration of the methyl ether of m-tert-butylphenol(Ref 3); and *4-(tert-Butyl)-2,3,6-trinitroanisole* (called 2.3.5-Trinitro-4-methoxy-1-tert-butyl -benzol in Ger), yel ndls(from alc), mp 74-5° (Refs 1 & 2). The expl props of these compds were not detd

*Refs:* 1)Beil **6**, 525 2)A.Baur,Ber **27**, 1619 (1894) & JCS **66** I, 450(1894) 3)M.S.Carpenter et al,JOC **16**, 608(1951) & CA **46**, 1494(1952)

**Butyl Azide.** See under n-Butane

**Butylbenzamide and Derivatives**

*Butylbenzamide,* $C_4H_9.NH.OC.C_6H_5$. Several isomers are described in Beil **9**, (97) & [166]

*Mononitrobutylbenzamide,* $C_4H_9.NH.OC.C_6H_4.NO_2$. Two isomers are described in Beil **9**, [271]

*Dinitrobutylbenzamide,* $C_{11}H_{13}N_3O_5$ - not found in Beil

**Trinitrobutylbenzamide,** $C_{11}H_{12}N_4O_7$, mw 312.24, N 17.95%. Three isomers are discussed in the literature: *N-(n-Butyl)-N,3,5-trinitrobenzamide,* $CH_3(CH_2)_3.N(NO_2).OC.C_6H_3(NO_2)_2$, no props given; was obtd as the residue from reaction of 3,5-dinitrobenzoyl chloride with the Na salt of N-nitrobutyl-amine(Ref 2); *N-(sec-butyl)-N,3,5-trinitrobenzamide,* $C_2H_5.CH(CH_3).N(NO_2).OC.C_6H_3(NO_2)_2$, prepn & props to be reported by White(Ref 2); and *N-(iso-butyl)-N,3,5-trinitrobenzamide,* $(CH_3)_2CH.CH_2.N(NO_2).C_6H_3(NO_2)_2$, prepn & props not given(Ref 2). Their expl props were not detd

An expl compd, *N-(1,1,1-Trinitro-2-butyl) -benzamide* [called by us N-(1,1,1-Trinitro-sec -butyl)-benzamide or N-(Trinitro-1-methyl -propyl)-benzamide], $CH_3.CH_2.\underset{\displaystyle C(NO_2)_3}{\underset{|}{CH}}.NH.OC.C_6H_5$, is described in Conf US Rubber CoQuartProg Rpt No **15**(1 May to 1 Aug, 1951),p 5

*Refs:* 1)Beil-not found 2)E.H.White, JACS **77**, 6020-1(1955) & CA **50**, 8527(1956)

**Butylbenzene and Derivatives**

**Butylbenzene, Phenyl Butane or Methylphenyl Propane**(called Butylbenzol, Phenylbutan or Methyl-phenyl-propan in Ger), $C_{10}H_{14}$; mw 134.21, N 10.51%. Four isomers exist: *n-Butylbenzene,* $CH_3(CH_2)_3.C_6H_5$, col liq, fr point -88°, bp 182°, flash p 160°F(TOC), d 0.8601 at 20°(Refs 1 , 4 & 5); *sec -Butylbenzene,* $CH_3.CH_2.CH(CH_3).C_6H_5$, col liq, fr point -75.8°, bp 173°, flash p 145°F(TOC), d 0.8621 at 20°(Refs 2, 4 & 5); *iso-Butylbenzene,* $(CH_3)_2CH.CH_2.C_6H_5$, col liq, fr p -52°, bp 173°, flash p 126°F(CC), d 0.867(Ref 3; Ref 4,p 794); *tert-Butylbenzene,* $(CH_3)_3C.C_6H_5$, col liq, fr point -58°, bp 168°, flash p 140°F(TOC), d 0.8665 at 20° (Refs 3, 4 & 5). Other props & methods of prepn are given in the Refs

*Refs:* 1)Beil **5**, 413, (201) & [317] 2)Beil **5**, 414, (202) & [319] 3)Beil **5**, 415, (203) & [320] 4)Sax(1957), 399 & 794 5)CondChemDict (1961), 183

**Mononitrobutylbenzene,** $C_{10}H_{13}NO_2$; mw 179.21, N 7.82%. A number of isomers of the type *Butyl-nitrobenzene,* $C_4H_9.C_6H_4.NO_2$, and *Nitrobutyl-benzene,* $O_2N.C_4H_8.C_6H_5$, of n-, sec-, iso-, & tert-butylbenzenes are described in the literature. All of these compds are low boiling, oily liquids, some of which are unstable. Their props & methods of prepn are given in Beil **5**,414,415,417,418,(201,202,203) & [318,319,320,321]

**Dinitrobutylbenzene,** $C_{10}H_{12}N_2O_4$; mw 224.21, N 12.50%. The following isomers are described in the literature: *2,4-Dinitro-1-(sec-butyl) -benzene,* $C_2H_5.CH(CH_3).C_6H_3(NO_2)_2$, liq, bp 143-4° at 2mm & 161-2° at 5mm, d 1.2195 at 25°, $n_D$ 1.5534 at 14.3°(Ref 3); *2,4,-Dinitro-1 -(iso-butyl)-benzene,* $(CH_3)_2CH.CH_2.C_6H_3(NO_2)_2$, liq, bp 158-9° at 2mm, d 1.2134 at 25°, $n_D$ 1.5479 at 25°(Ref 3); *2,4,-Dinitro-1 -(tert-butyl)-benzene,* $(CH_3)_3C.C_6H_3(NO_2)_2$, yel to col prisms(from dil alc), mp 61-2°, bp 185° at 15mm(Refs 1,6,7,8 & 9); UV spectra (Ref 5). Other props and methods of prepn of

dinitrobutylbenzenes are given in the Refs

The dinitro derivs of sec- & tert -butylbenzenes were proposed as ingredients of plastic expls contg PETN or RDX(Ref 2) and as ingredients of a plastic dynamite(Ref 3)

*Refs:* 1)Beil **5**, 418, (203) & [321] 2)H.R. Wright & W.G.Allan, BritP 5806012(1947) & CA **41**, 7120(1947) 3)T.E.Zalesskaya, ZhObshchKhim **17**, 489(1947) & CA **42**, 844 (1948) 4)H.R.Wright & W.G.Allan, USP 2439328(1948) & CA **42**, 4350(1948) 5)T. Canback, Farm Revy(Stockholm) **48**, 217, 234, 249(1949) & CA **43**, 6175(1949) 6)M.S. Carpenter et al, JOC **16**, 586(1951) & CA **46**, 1495(1952) 7)H.J.B.Biekart et al, Rec **71**, 332(1952) & CA **46**, 11127(1952) 8)N.M.Löfgren & B.Takman,ActaChemScand **6**, 1006(1952) & CA **47**, 8027(1953) 9)N.M.Cullinane & D.M. Leyshon, JCS **1954**, 2942 & CA **49**, 12323(1955)

**Trinitrobutylbenzene**, $C_{10}H_{11}N_3O_6$; mw 269.21, N 15.61%. The following isomers are known: *2,4-Dinitro-1-(2-nitro-iso-butyl)-benzene or 2,4-Dinitro-1-(2-methyl-2-nitropropyl)-benzene,* $(CH_3)_2.C(NO_2).CH_2.C_6H_3(NO_2)_2$, crysts, mp 68-9°; was prepd by reaction or 2,4-dinitrobenzyl chloride with Na salt of 2-propanenitronate (Ref 3) and *eso-Trinitro-(tert-butyl)-benzene,* $(CH_3)_3C.C_6H_2(NO_2)_3$, yel wh ndls(from alc), mp 108-9°; was prepd by nitrating dinitro-tert -butyl-benzene(Refs 1 & 2). The expls props of these compds were not detd

*Refs:* 1)Beil **5**, 418 2)A.Baur, Ber **27**, 1610 (1894) & JCS **66** I, 445(1894) 3)H.B.Hass & M.L.Bender, JACS **71**, 3485(1949) & CA **45**, 131(1951)

**Butyl Borate.** See under Borates

**Butyl Butyramide, Trinitro Derivative.** An expl compd called *N-(1,1,1-Trinitro-2-butyl) -butyramide,* $H_3C.CH_2.CH_2.CO.NH.CH(CH_2.CH_3).C(NO_2)_3$ is described in Conf US Rubber Co Quart Prog Rept No **15**(1 May–1 Aug, 1951),p 4

**n-Butylbutyrate,4,4,4-Trinitro.** See n-Butyl -4,4,4-trinitrobutyrate

**iso-Butylcarbamyl Azide**(called N-Isobutyl -carbamidsäureazid in Ger), $(CH_3)_2CH.CH_2.NH.CO.N_3$; mw 142.16, N 39.41%; liq, bp 94° at 22mm; sol in alc or eth; was prepd from iso-butylisocyanate and $HN_3$ in eth

*Refs:* 1)Beil **4**, (376) 2)E.Oliveri-Mandalà & F.Noto, Gazz **43** I, 519(1913) & JCS **104** I, 716(1913)

**Butylcarbinol.** See Amyl Alcohols; Vol 1,p A394

**Butyl "Cellosolve", Glycol Monobutyl Ether or 2-Butoxyethanol**(called Äthylenglykolmonobutyläther in Ger), $C_4H_9.O.CH_2.CH_2.OH$; mw 118.17, O 27.08%; col liq, fr point <-40°, bp 135°, flash p 141°F(CC), d 0.9311 at 20°; MAC 200ppm in air or 965mg per $m^3$ of air(Ref 2). Other props & methods of prepn are given in Refs 1, 2 & 4

It is used as a solv for NC, resins, oils & other materials. Zenftman & Forlin(Ref 3) patented fuse compns which can be continously extruded provided a thermoplastic binder or special antihardening agent is included in the formulation. Such a compn consisted of fuse powder 79.6(a mixt of $Pb_3O_4$ 41, $KNO_3$ 33 & Si 26%), colloided NC 20(NC 50, dibutylphthalate 48 & DPhA 2%) and 0.4% butyl "Cellosolve", or citric acid, or $KHC_2O_4.H_2O$

*Refs:* 1)Beil **1**, [519] 2)Sax(1947), 402 3)H.Zenftman & J.E.Forlin, USP 2590060 (1952) & CA **48**, 6700(1954) 4)CondChemDict (1961), 468

**Butyl Centralite.** See under Centralites

**Butyl-N-chloronitramine.** See under Butylamine

## Butylcresol and Derivatives

*Butylcresol, Butylhydroxytoluene or Butylhydroxymethylbenzene*(Butylkresol in Ger), $C_4H_9.C_6H_3(CH_3).OH$. Several isomers are described in Beil **6**, 550 & [507]

*Nitrobutylcresol,* $C_{11}H_{15}NO_3$. Several isomers are described in the literature

*Refs:* CA's **24**, 346[9], **29**, 1339[2]; **31**, 4658[8]; **43**, 3805a, **49**, 13145ef & 13175g; **50**, 6509a & 8727g

*Dinitrobutylcresol,* $C_{11}H_{14}N_2O_5$. Several isomers are described in the literature

*Refs:* CA's **31**, 4658[7]; **45**, 9500f and **49**, 13175e

**Trinitrobutylcresol**, $C_{11}H_{13}N_3O_7$; mw 299.24, N 14.04%. Two isomers are described in the literature: *5-(tert-Butyl)-3,4,6-trinitro-o-cresol; 5-(tert-Butyl)-2-hydroxy-1-methyl-3,4,6 -trinitrobenzene or 5-(tert-Butyl)-2-hydroxy-2 -hydroxy-3,4,6-trinitrotoluene*(called 2.4.5-Trinitro-6-oxy-1-methyl-3-tert-butylbenzol

in Ger), $O_2N.C = C(CH_3)-C.OH$
$(H_3C)_3C.C = C(NO_2)-C.NO_2$
yel ndls(from alc), mp 85-6°; was prepd by the action of $HNO_3$ on butyl-o-cresol in glacial AcOH at low temp(Refs 1 & 2); and *5-(tert-Butyl)-2,4,6-trinitro-m-cresol; 5-(tert-Butyl)-3-hydroxy-1-methyl-2,4,6-trinitrobenzene or 5-(tert-Butyl)-3-hydroxy-2,4,6-trin itrotoluene,*
$O_2N.C = C(CH_3)-C.NO_2$ ;
$(H_3C)_3C.C = C(NO_2)-C.OH$
crysts, mp 104°; was prepd by nitrating 5-(tert-butyl)-3-hydroxytoluene in benz with $HNO_3$ at low temp(Ref 3). Their expl props were not investigated
*Refs:* 1)Beil **6**, 550 2)A.Baur, Ber **27**, 1614 (1894) & JCS **66** I, 449(1894) 3)B.M.Dubinin & N.E.Kozhevnikova,ZhObshchKhim **21**, 662(1951) & CA **45**, 9500(1951)

**Butylene.** Same as Butene

**Butylene Glycol.** Same as Butanediol

**iso-Butylene Glycol.** Same as iso-Butanediol

**Butylene Glycol Ethers.** Several butylene glycol ethers are known and described in the literature. Edlund(Refs 1 & 2) prepd *iso-butylene glycol-2-monomethyl ether* [called 2-Methoxy-2-methyl-propanol-(1) in Ger], $(H_3C)_2C(OCH_3).CH_2.OH$, mw 104.15, O 30.73%, liq, bp 142° at 765mm, d 0.9333 at 20°, $n_D$ 1.4190 at 20°; and *iso-Butylene Glycol-2-monoethyl ether,* [called 2-Äthoxy-2-methyl-propanol-(1) in Ger], $(H_3C)_2C(OC_2H_5).CH_2.OH$, mw 118.17, O 27.08%, liq. bp 148, d 0.9073 at 20°, $n_D$ 1.4193 at 20°. These ethers were proposed as solvs for NC & other cellulose esters

Evans & Edlund(Ref 1 &3) reacted an aliphatic polyhydric alc with tert-butylene in the presence of a condensing agent(such as $H_2SO_4$) and obtd the following ethers: *mono-tert-Butylether of Ethylene Glycol* (called Äthylengylkol-mono-tert-butyläther in Ger), $(H_3C)_3.C.O.CH_2.CH_2OH$, mw 118.17, O 27.08% liq, bp 152.5° d 0.8970 at 20°, $n_D$ 1.41322 at 25°; *tert-Butyl-methylether of Ethylene Glycol*(called Äthylenglykol-methyläther-tert-butyläther in Ger), $(H_3C)_3.C.O.CH_2.CH_2.O.CH_3$, mw 132.20, O 24.21%, liq, bp 131-2°, d 0.8399 at 20°; and others. These and other ethers of glycol & glycerol can be used as solvs for NC and other cellulose esters, in the dyeing & explosives industry, and as cooling liquids for internal combustion engines
*Refs:* 1)Beil **1**, {2084, 2188} 2)K.R.Edlund, USP 1968032(1934) & CA **28**, 5832(1934) 3)T. Evans & K.R.Edlund,USP 1968033(1934) & CA **28**, 5832(1934)

**Butylene Oxides; Tetrahydrofuran or Tetramethylene Oxide,** $C_4H_8O$; mw 72.10, O 22.19%. Several isomers are known. A liq mixt of isomeric butylene oxides has the props: bp 62-5°, flash p 5°F, pour p -150°, d 0.826 at 25°, vap d 2.49; highly toxic liq; dangerous when exposed to heat or flame; expl range 1.5 to 18.3%(Ref 2). Other props & methods of prepn are given in the Refs. The 1,4-isomer (tetrahydrofuran or tetramethylene oxide) is described in detail in the Refs. Butylene oxides are used as solvs & as org intermediates
*Refs:* 1)Beil **17**, 10, (5) & [15] 2)Sax(1957), 405 & 1166 3)CondChemDict(1961), 186 & 1122

**Butylene Ozonides.** Harries et al(Refs 1 & 2) prepd the normal *monomeric Butylene Ozonide,* $(CH_3.CH_2-)_2O_3$; mw 104.10, O 46.11%; liq, bp 15-16° at 20mm, d 1.0217 at 22°, $n_D$ 1.3855 at 22°; decomp and turns brown with NaOH; expl violently when heated in a tube to ca 125°; was obtd in addn to the dimeric ozonide by the reaction of butylene and ozone in liq methyl chloride; normal *dimeric Butylene Ozonide,* $[(CH_3.CH_2)_2O_3]_2$; mw 208.21, O 46.11%; viscous liq, almost odorless, bp expl when heated to ca 125°, d 1.17 at 20°; sol in most org solvs; v sl sol in w. Using "crude"(unwashed) $O_3$, Harries et al(Refs 1 & 2) also obtd *monomeric Butylene Oxozonide,* $C_4H_8O_4$; mw 120.10, O 53.29%, liq, bp 20-2° at 20mm, d 1.0336 at 20°, $n_D$ 1.38404 at 20°; and *dimeric Butylene Oxozonide,* $(C_4H_8O_4)_2$; mw 240.21, O 53.29%; oil like glycerol and smelling like paraldehyde, fr p -80° solidifying to a glassy mass, bp dec & expl violently when heated to ca 125°, d 1.1604 at 19°, $n_D$ 1.43167 at 19°; readily sol in org solvs, except petr eth or w. All of these ozonides are decompd by w into acetaldehyde, AcOH, $H_2O_2$ & O

The ozonization of butylenes, aldehydes & acetone both in the gaseous phase and in soln at low temp has been described by Briner & Meier(Ref 3). They obtd the same expls

ozonides as Harries(Ref 2); and by hydrolysis & study of the products formed, Briner & Meier were able to distinguish one ozonide from another

Rieche & Meister(Ref 4) found that cautious heating of butylene ozonide in vacuo caused it to undergo cleavage and there formed, at about 80°, a wh cryst mass which was extremely expl. This product was identified as pure *dimeric ethylidene peroxide*(Ref 6). In the course of a study of ozonides and their decompn Rieche et al(Refs 5 & 6) prepd *2,3-Butylene Ozonide*, $CH_3.\underbrace{CH.O.O.CH}_{O}.CH_3$, bp 35° at 100mm, d 1.027 at 19°; an expl compd but not sensitive to shock at RT; the distn residue was a polymer more stable than the dimer

Garvin & Schubert(Ref 7) prepd *iso-Butylene Ozonide*, a col liq, expldg violently when heated; vap press 25mm at 18.4°, $n_D$ 1.388 at 18.0°. They detd its IR spectra as a means of identification

*Refs:* 1)Beil **1**, (85) 2)C.Harries et al,Ann **390**,241,245(1912) & CA **6**, 2754(1912) 3)E. Briner & R.Meier,Helv **12**, 529-53(1929) & CA **23**, 5155(1929) 4)A.Rieche & R.Meister, Ber **72**, 1935(1939) & CA **34**, 712(1940) 5)A.Rieche et al,Ann **553**, 187(1942) & CA **37**, 5365, (1943) 6)Tobolsky & Mesrobian(1954), 50, 180 7)D.Garvin & C.Schubert, JPhChem **60**, 807-8 (1956)

**Butyl Ester of Peroxyacetic Acid.** Same as Butyl Peroxyacetate

**Butyl Ester of Peroxybenzoic Acid.** Same as Butyl Peroxybenzoate

### Butylethanolamine and Derivatives

*Butylethanolamine or Butylaminoethanol* [called β-Butyl-amino-äthylalkohol or Butyl-(β-oxy-äthyl)-amin in Ger], $CH_3.(CH_2)_3.NH.CH_2.CH_2.OH$; mw 117.19, N 11.95%; col liq, bp 199-200° at 756mm, flash p 170°F(OC), d 0.891 at 20°, $n_D$ 1.4437 at 20°; readily sol in alc, eth or w; its toxicity details are unknown; was prepd from butylamine & ethylene oxide (Refs 1 & 2). It forms salts & nitrated derivs, some of which are expl. Isomers of butylethanolamine are also known & described in the literature

*Refs:* 1)Beil **4**, 283 2)Sax(1957), 405 3)CondChemDict(1961), 188

**Butylethanolamine Dinitrate,** $C_4H_9.NH.CH_2.CH_2(ONO_2).HNO_3$; mw 225.20, N 18.66%; compd prepd by nitrating n-butyl-ethanolamine with mixed acid at 0-10° and pptg the product by pouring into ice & w; was proposed for use as an expl or in expl mixts

*Refs:* 1)Beil-not found 2)Dynamit-AG,BritP 358157(1930) & CA **26**, 6141(1932)

**1-(N-Butylnitramino)-2-nitroxy-ethane or [1-(N-Butylnitramino)-ethan-2-ol] Nitrate,** $C_4H_9.N(NO_2).CH_2.CH_2.ONO_2$; mw 207.19, N 20.28%; pale yel oil fr p -9-9°, $n_D$ 1.4750 at 20°; was prepd from 2-ethanol-butylamine, nitric acid, acetic anhydride & a chloride catalyst such as $ZnCl_2$. It was proposed as a plasticizer for use in double-base proplnts.

*Refs:* 1)Beil-not found 2)A.T.Blomquist & F.T.Fiedorek,USP 2485855(1949), pp 6, 14 & CA **44**, 3516-17(1950)

**Butylethylcarbamate.** Same as Butylurethane

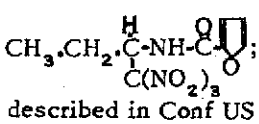
### Butylethyltoluene and Derivatives

*3-(tert-Butyl)-5-ethyltoluene,* $H_3C(C_2H_5).C_6H_3.C(CH_3)_3$, liq, bp 71° at 2mm, is described in Ref 2

**3-(tert-Butyl)-5-ethyltoluene, Trinitro Derivative,** $H_3C(C_2H_5).C_6(NO_2)_3.C(CH_3)_3$; mw 311.29, N 13.50%; pale yel stout ndls(from MeOH), having a musk odor, mp 75-76.5°; was prepd by nitrating 3-(tert-butyl)-5-ethyltoluene. No expl props of this compd were detd

*Refs:* 1)Beil-not found 2)M.S.Carpenter & W.M. Easter,JOC **19**, 88,94(1954) & CA **49**, 3043(1955)

**Butylfuroamide, Trinitro Derivative.** An expl compd called *N-(1,1,1-Trinitro-2-butyl)-furoamide,*



; mw 302.20, N 18.54%; described in Conf US Rubber Co Quart Prog Report No **15**(1 May to 1 Aug 1954), pp 5 & 6

### Butylguanidine and Derivatives

*Butylguanidine,* $C_4H_9.NH.C(:NH).NH_2$; mw 115.18, N 36.49%; may be considered the parent compd of its various salts & nitrated derivs; was first prepd by Paden & MacLean(Ref

3) by the reaction of butylamine and its acid salt with $NH_2.CN$ in aq soln at 80-170°; and later prepd by Roche et al(Ref 4) by the oxidn of arginine in aq alk soln. Davis & Elderfield (Ref 2) had earlier prepd salts of butylguanidine, such as its *Nitrate*, mp 69° and *Picrate*, mp 154.5°. A number of other investigators have since prepd these & other salts of butylgaunidine
*Refs:* 1)Beil-not found 2)T.L.Davis & R.C. Elderfield, JACS **54**, 1499(1932) & CA **26**,2708 (1932) 3)J.H.Paden & A.F.MacLean,USP 2425341(1947) & CA **41**, 7414(1947) 4)J.Roche et al, BullSocChimBiol **37**,55(1955) & CA **50**, 4022(1956)

**Mononitrobutylguanidine or Butylmononitroguanidine**, $C_5H_{12}N_4O_2$; mw 160.18, N 34.98%. The following isomers are described in the literature: *N'-Nitro-N-butylguanidine*, $CH_3(CH_2)_3NH.C(:NH).NH.NO_2$, ndls(from w) or prisms(from alc), mp 84-5°(Refs 1,3,4,5 & 8); IR spectra(Ref 6); *N'-Nitro-N-(iso-butyl)-guanidine*, $(CH_3)_2.CH.CH_2.NH.C(:NH).NH.NO_2$, col pltlts (from aq alc), mp 121-22°(Refs 2,3,4,5 & 8); and *N'-Nitro-N(tert-butyl)-guanidine* [called 1-(t -butyl)-3-nitroguanidine by Fishbein & Gallaghan], $(H_3C)_3.CNH.C(:NH).NH.NO_2$, col crysts(from MeOH), mp 199-201°; was prepd by heating tert-butylamine, 2-methyl-1(or 3)-nitro-2 -thiopseudourea & abs alc on a w bath at 45° for 6 min(Ref 7). Methods of prepg the other isomers are given in the Refs
*Refs:* 1)Beil **4**, [635] 2)Beil **4**, [640] 3)T.L. Davis & S.B.Luce, JACS **49**,2303-5(1927) & CA **21**,3348(1927) 4)A.F.McKay & G.F.Wright, JACS **69**,3029(1947)& CA **42**,1567(1948) 5)A.F. McKay,USP 2559085(1951) & CA **46**,3562(1952) 6)E.Lieber et al,AnalChem **23**,1594-1604(1951) & CA **46**, 3857(1952) 7)L.Fishbein & J.A. Gallaghan,JACS **76**,1879(1954) & CA **49**,6838 (1955) 8)A.F.McKay, CanP 519448(1955) & CA **50**, 12107(1956)

**N-Nitroso-N-(n-butyl)-N'-nitroguanidine** [called 1-Butyl-3-nitro-1-nitrosoguanidine in CA 5th Decennial Formula Index(1947-1956),p 132F], $CH_3.(CH_2)_3.N(NO).C(:NH).NH.NO_2$; mw 193.16, N 21.76%; crysts(from MeOH), mp 121°(dec); was prepd by nitrosation of butylnitroguanidine dissolved in aq $HNO_3$ soln(Ref 2)A compd, patented by McKay(Ref 3), was called 1-butyl-1 -nitroso-2-nitroguanidine, mp 113°
*Refs:* 1)Beil-not found 2)J.F.McKay,JACS **71**, 1969(1949) & CA **43**, 9035(1949) 3)J.F.McKay, USP 2555498(1951) & CA **46**,1034(1952)

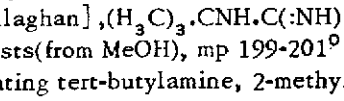
**N-Nitro-N-(n-butyl)-N'-nitroguanidine**(called 1-n-Butyl-1,3-dinitroguanidine by Meen & Wright), $C_4H_9.N(NO_2).C(:NH).NH.NO_2$, mw 205.18, N 34.14%; crysts(from chlf + $CCl_4$), mp 71-2°; compd is 0.4% sol in w at 25°; very sol in most org solvs; was prepd by treating 1-(n-butyl)-2-nitroguanidine, $[C_4H_9.NH.C(:N.NO_2).-NH_2]$, with $HNO_3$ & $Ac_2O$ for 1hr at 20-2°. This compd was rapidly cleaved by dil KOH to yield K nitrocyanamide & n-butylnitramine, isolated as the monohydrate of the Ba salt. The expl props of the dinitro deriv were not detd
*Refs:* 1)Beil-not found 2)R.H.Meen & G.F. Wright, JACS **74**, 2077-79(1952) & CA **48**,2600 (1954)

**Butyl Hydride.** Same as n-Butane

### Butylhydrindene and Derivatives

*5-(tert-Butyl)-hydrindene*, $C_{13}H_{18}$, liq, bp 237-40°, is described in Refs 1 & 2
*6,7-Dinitro-5-(tert-butyl)-hydrindene*, $C_{13}H_{16}(NO_2)_2$, crysts, mp 121-4°(Refs 1 & 2)

**4,6,7-Trinitro-5-(tert-butyl)-hydrindene or 4,6,7-Trinitro-5-(tert-butyl)-indan,**



mw 309.27, N 13.59%; crysts(from alc), having an odor of musk, mp 140°; was prepd by nitrating the dinitro deriv with mixed acid at 50-5°. No expl props were detd
*Refs:* 1)Beil **5**,506, [400] 2)Fabrique de Thann et Mulhouse, GerP 80158; Frdl **4**, 1295(1894-7)

**Butylhydroperoxide or Butylhydroxyperoxide** (called Butyl-hydroperoxyd in Ger), $C_4H_{10}O_2$; mw 90.12, N 35.51%. Four isomers are described in the literature: *n-Butylhydroperoxide*, $CH_3.(CH_2)_2.CH_2.O.OH$, liq, azeotrope bp 28-9° at 100mm(Ref 7),pure compd bp 40-2° at 8mm(Ref 9); d 0.9078 at 20°, $n_D$ 1.4032 at 20°; was previously reported as a pro -knock additive in a spark ignition engine(Ref 6), but its props & method of synthesis were detd by Lindstrom(Ref 7); a relatively stable compd not detonated by impact or by heating in a free flame; its thermal decompn was studied by Thomas(Ref 11) and by Mosher & Wurster(Ref 12); Williams & Mosher(Ref 9) reported a new & practical synthesis by the reaction of n-butyl methane sulfonate with 30% $H_2O_2$ and Walling & Buckler(Ref 13) by addn of Grignard reagents to oxygen-saturated solvs; IR spectra were detd by

Williams & Mosher(Ref 10); *sec-Butyl -hydroperoxide*, $C_2H_5.CH(CH_3).O.OH$, liq, azeotrope bp 36° at 100mm(Ref 7), pure compd 41-2° at 11mm(Ref 9), d 0.868 at 20°, $n_D$ 1.4269 at 25°; was previously reported as a pro-knock additive in a spark ign engine(Ref 6), but its props & method of prepn were detd by Lindstrom(Ref 7); a relatively stable compd not detonated by impact or by heating in a free flame; its thermal decompn was studied by Thomas (Ref 11); Williams & Mosher(Ref 9) reported a synthesis by the reaction of sec-butyl methane sulfonate with alk $H_2O_2$ in MeOH; IR spectra were detd by Williams & Mosher(Ref 10); polarographic study by Skoog & Lauwzecha(Ref 14); *iso -Butylhydroperoxide*, $(CH_3)_2CH.CH_2.O.OH$, liq; was reported as a pro-knock additive in a spark ignition engine(Ref 6) but its props & method of prepn were not given; and *tert -Butylhydroperoxide*, $(CH_3)_3C.O.OH$, liq, fr p 3.8-4.5°, bp 33-34° at 17mm, flash p 55°F(CC), d 0.8930 at 20°, $n_D$ 1.4013 at 20°; can be prepd from anhyd tert-butylalcohol & $H_2O_2$ by subjecting it to fractional distn under reduced pressure in the presence of dehydrating agents or by other methods(Ref 1,2,3,5 & 8); it is stable at RT but expl violently when heated in an open flame; explosions can also result if distilled under normal press. Due to its property of being a good polymerization catalyst, tert-butylhydroperoxide can be used for curing some polyester resins("Paraplex") which may be used as fuels & binding agents in expl or proplnt compns. It has been used in some Aerojet solid proplnts (See RL-206 Propellant under Bentonite and Ref 4). The combustion product, manufd by Lucidol Div of Wallace & Tiernan, Inc, Buffalo, NY is a mixt contg tert-butylhydroperoxide(60% min), di-(tert-butyl)-peroxide & tert-butylalcohol

*Refs:* 1)Beil **1**, {1579} 2)N.A.Milas & S.A. Harries, JACS **60**,2434(1938) 3)N.A.Milas & D.M.Surgenor, JACS **68**,205(1946) 4)Aerojet EngrgCorpRpt No **192**(1946),16-7 5)R.Criegee & H.Dietrich,Ann **560**,135(1948) 6)D.Downs et al, TrRoySoc **243A**,299(1951) & CA **46**,244(1952) 7)E.G.Lindstrom,JACS **75**,5124(1953) & CA **49**,7846(1955) 8)Tobolsky & Mesrobian(1954), 3, 158 & 177 9)H.R.Williams & H.S.Mosher, JACS **76**,2984(1954) & CA **49**,8783(1955) 10)H.R. Williams & H.S.Mosher, AnalChem **27**,517(1955) & CA **49**,10061(1955) 11)J.R.Thomas, JACS **77**, 246(1955) & CA **49**,508 9(1955) 12)H.S. Mosher & C.F.Wurster,JACS **77**, 5451(1955) & CA **50**,6305(1956) 13)C.Walling & S.A.Buckler,JACS **77**,6032(1955) & CA **50**,8505(1956) 14)D.A. Skoog & A.B.H.Lauwzecha, AnalChem **28**, 825(1956) & CA **50**,10561(1956) 15)Sax(1957), 406 16)CondChemDict(1961), 186

**tert-Butylhydroperoxide-p-nitrobenzoate**, $(H_3C)_3.C.O.O.\overset{O}{\overset{\|}{C}}.C_6H_4.NO_2$, mw 239.22, N 5.86%, O 33.44%; thin yel lfts(from MeOH), mp 78°; was prepd by reacting the peroxide with the calcd amt of p-nitrobenzoylchloride in abs pyridine. A number of other hydroperoxide-nitrobenzoates are expl compds

*Refs:* 1)Beil-not found 2)R.Criegee & H. Dietrich,Ann **560**,138(1948) & CA **43**,6189(1949)

**tert-Butylhydroperoxide, Oxalic Acid Ester**(no formula given in Ref 1). An expl compd which detonated on removal from a freezing mixt

*Refs:* 1)W.E.Vaughan, private communication cited in Tobolsky & Mesrobian(1954), 178 2)CA Decennial Index 1947-1956-not found

**Butylhydroxybenzene.** Same as Butylphenol

**Butylhydroxymethylbenzene.** Same as Butylcresol

**tert-Butylhydroxymethylperoxide**, $(CH_3)_3.C.O.O.-CH_2OH$; mw 192.21, O 24.97%; liq, bp 52-53° at 8-9mm, d 0.96 at 20°, $n_D$ 1.4128 at 20°; was prepd by gradually adding tert-butylhydroperoxide to 36-8% formalin soln at RT & vacuum distilling the product and also by mixing equimolar amts of 30% aq solns of $CH_2O$ & $(CH_3)_3C.O.OH$, followed by distn(Refs 2 & 3). The product is useful as a catalysts for polymerization of unsatd compds

*Refs:* 1)Beil-not found 2)F.H.Dickey,USP 2400041(1946) & CA **40**, 5068(1946) 3)F.H. Dickey et al, JACS **71**,1433(1949) 4)Tobolsky & Mesrobian(1954),173

**2-Butyl-2-(hydroxymethyl)-1,3-propanediol.** An expl compd listed in Conf ADL Rpt on "Study of Pure Explosive Compounds", Part IV(1952),p 586

**Butylhydroxytoluene.** Same as Butylcresol

## iso-Butylmalonic Acid and Derivatives

*iso-Butylmalonic Acid* [called Isobutylmalonsäure or 3-Methyl-butan-dicarbonsäure-(1.1) in Ger], $(CH_3)_2CH.CH_2.CH(COOH)_2$; mw 160.17, O 39.96%; crysts(from benz), mp 108°, dec on continued heating at 115°; sol in w, alc or eth; other props

& methods of prepn are given in Beil **2**,683, (284) & {1756}

*iso-Butylmalonic Acid Monohydrazide,*
$(CH_3)_2CH.CH_2.CH(COOH)$; mw 174.20, N 16.08%;
$CO.NH.NH_2$
pltlts(from dil eth), mp 154-55°(dec); sol in alc or w; was prepd by heating the K salt of iso -butylmalonic acid monoethyl ester with hydrazine hydrate(Refs 1 & 2)

*Refs:* 1)Beil **2**,{1757} 2)T.Curtius & M. Schenck, JPraktChem **125**, 255,256(1930) & CA **24**,3216(1930)

**iso-Butylmalonic Acid Monoazide,**
$(CH_3)_2CH.CH_2.CH(COOH)$; mw 185.18, N 22.69%;
$CO.N_3$
yel oil having a pungent odor, expl mildly when heated, producing a flame; was prepd by treating an eth soln of the monohydrazide & $NaNO_2$ in dil NaOH with concd HCl and cooling (Refs 1 & 2)

*Refs:* 1)Beil **2**, {1757} 2)T.Curtius & M. Schenck, JPraktChem **125**,257(1930) & CA **24**, 3216(1930)

**iso-Butylmalonic Acid Amide Azide,**
$(CH_3)_2CH.CH_2.CH(CONH_2)$; mw 184.20, N 30.42%;
$CO.N_3$
ndls, mp 87°(dec), expl mildly when heated on a spatula; sol in alc or benz; sl sol in eth, chlf or $CCl_4$; almost insol in w; was obtd when the monohydrazide was treated with $HNO_2$ in the absence of ether(Refs 1 & 2)

*Refs:* 1)Beil **2**, {1757-8} 2)T.Curtius & M. Schenck, JPrakChem **125**,216,264 & CA **24**, 3216(1930)

**iso-Butylmalonic Acid Nitril Azide,**
$(CH_3)_2CH.CH_2.CH(CN)$; mw 166.18, N 33.72%;
$CO.N_3$
yel oil having a pungent odor, expl when heated in a flame; sol in eth or w; was prepd by treating iso-butycyanoacetic acid hydrazide with $NaNO_2$ & an excess of HCl(Refs 1 & 2)

*Refs:* 1)Beil **2**,{1758} 2)A.Darapsky et al, JPrakChem **146**,260(1936) & CA **31**,368(1937)

**Butyl Mercaptan**, $C_4H_9.SH$; mw 90.18. Flammable liq having a"skunk-like"odor. Four isomers exist and they are described in the literature (Refs 1, 2 & 4). Ref 3 lists a butyl mercaptan with bp 206-10°F(97-99°C), sp gr 0.835, fl p -162°F(-108°C) which has been considered for use as a rocket fuel. This material is probably a coml mixt of various isomers of butyl mercaptan

*Refs:* 1)Beil **1**,370,373,378,383,(187,189,191) & [398,403,404,405,412,416] 2)Sax(1957),407 3)DictGuidedMissiles(1959),106 4)CondChemDict (1961),187,622

**Butylmethoxybenzene.** Same as Butylanisole

**Butylmethoxymethylbenzene.** Same as Butylmethylanisole

**Butylmethoxytoluene.** Same as Butylmethylanisole

**Butylmethylaniline.** Same as Butylaminotoluene

**Butylmethylanisole and Derivatives**

*Butylmethylanisole, Butylmethoxymethylbenzene, or Butylmethoxytoluene*(called Methyläther des Methyl-butyl-phenol, Methoxy-methyl-butyl -benzol, or Butyl-kresol-methyläther in Ger), $C_4H_9.C_6H_3(CH_3).OCH_3$. Two isomers of tert-butylmethylanisole are described in the literature

*Refs:* 1)Beil **6**,550 & [507] 2)A.Baur,Ber **27**, 1614-19(1894) & JCS **66** I,450(1894)

*Dinitromethylanisole*, $C_{12}H_{16}N_2O_5$, mw 268.26, N 10.44%. Two isomers are described in the literature

*Refs:* 1)Beil **6**,550(mentioned only) 2)A.Baur, Ber **27**, 1614-19(1894) & JCS **66** I, 450(1894) 3)H.Barbier,Helv **11**,158 & 160(1928)

**Trinitrobutylmethylanisole**, $C_{12}H_{15}N_3O_7$, mw 313.26, N 13.42%. Two isomers are described in the literature: *2,4,6-Trinitro-5-(tert-butyl)-3 -methyl-anizole or 2,4,6-Trinitro-3-methoxy-5 -(tert-butyl)-toluene*, $C_4H_9.C_6(NO_2)_3(CH_3).O.CH_3$, lt yel crysts, mp 88°. Can be prepd either by nitration of 5-(tert-butyl)-3-methyl-anisole with $HNO_3$ in $Ac_2O$ and then with mixed acid or by methylation of 5-(tert-butyl)-3-hydroxy-2,4,6 -trinitrotoluene with $Me_2SO_4$(Refs 1, 2 & 3); and *3,5,6-Trinitro-4-(tert-butyl)-2-methyl-anisole or 3,4,6-Trinitro-5-(tert-butyl)-2-methoxy-toluene,* yel ndls, having an odor of musk, mp 69-70°; was prepd from the Ag salt of butyltrinitro-ortho -cresol as described in Ref 2, or by nitrating butyl-ortho-methoxytoluene(Ref 2). The expl props of these trinitro-derivs were not detd

*Refs:* 1)Beil **6**,[507-8] 2)A.Baur, Ber **27**, 1614-15 & 1618(1894) & JCS **66** I, 450(1894) 3)B.M.Dubinin & N.E.Kozhevnikova, ZhObshch-Khim **21**.662-8(1951) & CA **45**,9500(1951)

**Butylmethylbenzene.** Same as Butyltoluene

**Butylmethylhydroxybenzene.** Same as Butylcresol

**Butylnitramine.** See under Butylamine

**Butyl Nitrate.** See under Butanol

**Butyl Nitrite.** See under Butanol

**Butyl Oxalate,** $H_9C_4.OO.C.COO.C_4H_9$; mw 202.24, O 31.64%; liq, bp 243°, fl p 265°F(OC), d 0.989-0.993, vap d 7.0; toxicity details are unknown(Ref 3); was tried in France as a possible substitute for Centralite in solventless smokeless proplnts(poudres SD). Proplnts prepd from NC, NG, 4% butyl oxalate & 2% EtCentr were more brittle and less stable than corresponding proplnts contg EtCentr alone(Ref 2)
*Refs:* 1)Beil-not found 2)R.Dalbert & H. Ficheroulle, MP **30**,284 & 288(1948) 3)Sax (1957),410

**Butyl Peroxide.** See Dibutyl Peroxide

**Butyl Peroxyacetate or Butyl Ester of Peroxyacetic Acid,** $C_6H_{12}O_3$; mw 132.16, O 36.32%. One isomer is described in the literature: *tert-Butyl Peroxyacetate*(the coml product of Lucidol Div of Novadel-Agene Corp, Buffalo, NY, is called t-Butyl Peracetate); $(CH_3)_3C.OO.OC.CH_3$, clear liq, bp 30° at 50mm, d 0.883 at 22.5°; $n_D$ 1.403 at 5°, fl p (COC) above 100° (coml product); expl violently when heated rapidly; the presence of benz prevents its expl decompn(Ref 10); IR spectra was detd by Davison(Ref 5)

The prepn of butyl peroxyacetate was patented by Milas(Ref 3) and by Warrick(Ref 4) who obtd the compd by cooling to 0° a soln of tert-butyl hydroperoxide & di-(tert-butyl) peroxide in pyridine, adding AcCl at 20-30°, washing with aq$Na_2CO_3$ & w, removing the pyridine, and distg the product at reduced press. Harman(Ref 6) and Bataafsche Petroleum(Ref 7) both patented its method of prepn by passing gaseous ketene into tert-butyric acid, contg a trace of $H_2SO_4$, over a period of 1 hr at 0-30°, and isolating the product by extraction with pentane

Butyl peroxyacetate is used as a polymerization initiator and catalyst.The coml product is described in Ref 2

The expln of butyl peroxyacetate which occurred on 23 Sept 1953 in the Novadel-Agene Corp, Lucidol Division plant at Tonawanda, NY; and in which 11 persons were killed and a number of others injured is reported by Martin(Ref 10). Dr Martin proposed a theory to explain the expln and conducted experiments which proved that rapid heating of butyl peroxyacetate to a critical temp will cause the compd to detonate violently. According to Martin, a report from the Bureau of Explosives, Dept of Commerce, indicated in their application of heat tests that butyl peroxyacetate failed to explode. This was explained on the basis of too low a rate of applying heat. The Bureau did detonate a mixt of the coml liq and a combustible org compd, such as cotton or woodflour, by initiation with a blasting cap. In inpact tests of the same combustible saturated with the liq. no explns occurred under drops of 10in. What actually caused the first mild expln, the subsequent fire, and detonation of carboys of butyl peroxyacetate have not been discovered
*Refs:* 1)Beil-not found 2)Lucidol Div, Novadel -Agene Corp,Buffalo,NY, Organic Peroxides Data Sheet No **34**(1950) 3)N.A.Milas,USP 2567615 (1951) & CA **46**,3069(1952) 4)E.L.Warrick,USP 2572227(1951) & CA **46**,772(1952) 5)W.H.T. Davison,JCS **1951**, 2456 & CA **46**,8965(1952) 6)D.Harman,USP 2608570(1952) & CA **48**,3387 (1954) 7)N.V.de Bataafsche Petroleum Maatschappij, BritP 66371(1952) & CA **47**, 5428(1953) 8)Tobolsky & Mesrobian(1954),182 9)Sax(1957)-not found 10)J.J.Martin, IEC **52**, No 4, 65A(1960)

**tert-Butyl Peroxybenzoate or Butyl Ester of Peroxybenzoic Acid.** $(CH_3)_3C.OO.OC.C_6H_5$; mw 194.22, O 24.71%; liq, fr p 8°, bp 113°(dec), flash p 66°F(CC), d 1.035 at 25°, vap press 0.33mm at 50°, vap d 6.69; very sol in alcohols, esters, ethers or ketones(Refs 6 & 8). Criegee (Ref 4) reported that when a lab worker attempted to purify tert-butyl peroxybenzoate by vac accdg to the method of Milas & Surgenor(Ref 2), a violent expln occurred because the distn temp reached 115°

The props of the coml product which contains a min of 95% tert-butyl peroxybenzoate are given in Ref 3

*Refs:* 1)Beil-not found 2)N.A.Milas & D.M. Surgenor,JACS **68**, 642(1946) 3)Lucidol Div, Novadel-Agene Corp, Buffalo,NY, Organic Peroxides Data Sheet No **27**(1949) 4)R.Criegee, AngChem **65**, 398-9(1943) & CA **47**, 11737(1953) 5)Tobolsky & Mesrobian(1954), 182 6)Sax(1957), 410 8)CondChemDict(1961),188

### Butylphenol and Derivatives

*Butylphenol or Butylhydroxybenzene,* $C_{10}H_{14}O$. Several isomers are described in Beil **6**,522,524, (259) & [485,487 & 489]

*Nitrobutylphenol,* $C_{10}H_{13}NO_3$. Two isomers are described in Beil **6**,525 & [488]

**Dinitrobutylphenol,** $C_{10}H_{12}N_2O_5$. One isomer *2,6-Dinitro-4-(tert-butyl)-phenol,* crysts, mp 97-8°, is described in Beil **6**, 525 & [489]

**Butylphenol or Butylhydroxybenzene, Trinitro Derivative.** $C_{10}H_{11}N_3O_7$; mw 285.21, N 14.73%. Only one isomer is described in the literature: *3-(tert-Butyl)-2,4,6-trinitrophenol,* $(CH_3)_3C\text{-}C_6H(OH)(NO_2)_3$ pale yel ndls(from alc), mp 172°; was obtd by nitrating methyl ether of m-tert -butylphenol with mixed acid at 10-25°. Its expl props were not detd

*Refs:* 1)Beil-not found 2)M.S.Carpenter et al, JOC **16**,608(1951) & CA **46**, 1493-4(1952)

**Butylphthalate.** See Dibutylphthalate

**Butyl Ricinoleate**(called Ricinolsäurebutylester in Ger), $C_{18}H_{33}O_3C_4H_9$; mw 354.56, O 13.54%; yel to col liq, bp 275° at 13mm, fl p 220°, d 0.906 at 22°(Refs 1,2,4 & 5); was first prepd by Walden(Refs 1 & 2) from ricinoleic acid, butyl alcohol & HCl. It was proposed as a deterrent surface agent for progressive burning proplnts (Ref 3). Because butyl ricinoleate is a non-solv for NC, but compatible with it, the coating does not penetrate the proplent grains during prolonged storage, as do some other coating compds

*Refs:* 1)Beil **3**, 388,(138) 2)P.Walden,Ber **36**, 782(1903) 3)H.M.Spurlin & G.H.Pfeiffer,USP 2187866(1940) & CA **34**,3918(1940) 4)Sax(1957), 411-12 5)CondChemDict(1961),189

**Butyl Rubber.** A synthetic rubber produced by copolymerization of isobutene(98%) with a small proportion(ca 2%) of isoprene or butadiene. Polymerization is conducted at -50 to 100° in a liquid hydrocarbon, with $AlCl_3$ as catalyst. Its outstanding property compared with other rubbers is impermeability to gases. The uncured rubber is tacky, but it may be compounded like natural rubber and vulcanized. Butyl rubber has good resistance to chemical attack and to aging even at high temps. It has superior vibration insulation characteristics and abrasion resistance, but relatively low tensile strength and poor flame resistance

Important uses of butyl rubber, other than as inner tubes or similar gas retaining applications, are as insulators, latex coatings and as binder fuels in solid rocket proplnts

*Ref:* CondChemDict(1961),189

**Butyl Tetryl.** See [2,4,6-Trinitro-N-nitro-N -(n-butyl)]-aniline; sym-Trinitrophenyl-N-(n -butylnitramine); or (2,4,5-Trinitrophenylnitramine) -n-butane under Tetranitro derivs of n-Butylaniline

### Butyltoluene and Derivatives

*Butyltoluene or Butylmethylbenzene*(called Butyl-toluol of methyl-butyl-benzol in Ger), $C_4H_9.C_6H_4.CH_3$; mw 148.24. Eight isomers are listed in Beil(Ref 1). Sax(Ref 2) lists the p-tert -butyl isomer

*Refs:* 1)Beil **5**,437,439,(209) & [333,334] 2)Sax(1957),413

**Mononitrobutyltoluene,** $C_4H_9.C_6H_3.NO_2.CH_3$; mw 193.24, N 7.25%. Several isomers are known and described in the literature: *2-Nitro-4-(sec-butyl) -toluene(Ref 5); 2-Nitro-4-(tert-butyl)-toluene* (Refs 2 & 4); *5-Nitro-3-(tert-butyl)-toluene*(Refs 1 & 3); *and 6-Nitro-3-(tert-butyl)-toluene*Ref 1)

*Refs:* 1)Beil **5**,438 2)Beil **5**, [334] 3)B.M. Dubinin & N.E.Kozhevnikova, ZhObschKhim **21**, 662(1951) & CA **45**,9500(1951) 4)M.S. Carpenter, JOC **16**,587(1951) & CA **46**,1491(1952) 5)N.M.Cullimane & D.M.Leyshon,JCS **1954**,2947 & CA **49**, 12324(1955)

**Dinitrobutyltoluene,** $C_4H_9.C_6H_2(NO_2)_2.CH_3$; mw 238.24, N 11.76%. Two isomers are known: *eso-Dinitro-3-(tert-butyl)-toluene,* ndls, mp 92°, bp ca 224-5°(in vacuo)(Refs 1 & 3) and *2,6-Dinitro*

*-4-(tert-butyl)-toluene*, grn-yel lfts(from dil alc), mp 94-5°(Refs 2,4,5,6 & 7). Other props & methods of prepn are given in the Refs
*Refs:* 1)Beil **5**,438 2)Beil **5**,439,(210) & [334] 3)A.Baur, Ber **24**,2835(1891) & Ber **27**,1624(1894) 4)M.Battegay & P.Haeffely, BullFr **35**,985(1924) & CA **19**,43(1925) 5)H.Barbier, 14-me Congrès de Chimie Industriele, Paris **1934**,4pp(Oct 21-7) and CA **29**,5821(1935) 6)M.S.Carpenter & W.M.Easter, JOC **19**, 87(1954) & CA **49**,3044(1955) 7)N.M. Cullinane & D.M.Leyshon, JCS **1954**,2947 & CA **49**,12323(1955)

**Trinitrobutyltoluene**, $C_4H_9.C_6H(NO_2)_3.CH_3$; mw 283.24, N 14.84%. Three isomers are described in the Literature: *2,4,6-Trinitro-3-(n-butyl) -toluene*, greenish ndls(from alc), becomes red and then yel-brn or exposure to light; mp 78.5°; was prepared by nitrating 3-butyltoluene at 10-20° (Refs 3 & 6); *2,4,6-Trinitro-3-(iso-butyl)-toluene*, crysts(from dil alc), having an odor resembling that of musk, mp 124°; was prepd by nitrating m-iso-butyltoluene(Refs 1 & 5); and*2,4,6-Trinitro -3-(tert-butyl)-toluene*, lt yel ndls(from alc), having an odor of musk, mp 96-7°; readily sol in alc, eth, chlf, benz & petr eth; insol in w; was prepd by nitrating m-tert-butyltoluene(Refs 2,4,6 & 7). Other props & methods of prepg the trinitro derivs are given in the Refs. Their expl props were not investigated
*Refs:* 1)Beil **5**,437 2)Beil **5**,438 3)Beil **5**, [333] 4)A.Baur, Ber **24**,2836-7(1891) 5)E.Knoevenagel, Ann **289**,165(1896) 6)R.DeCapeller, Helv **11**, 166-72(1928) & CA **22**,1339(1928) 7)A.V.Grosse et al, JOC **3**,448-55(1938) & CA **33**,2112(1939)

**2,4,5,6-Tetranitro-3-(tert-butyl)-toluene(?)**, $C_4H_9.C_6(NO_2)_4.CH_3$; mw 328.24, N 17.07%; pale yel plates(from MeOH), mp 222°; was obtd by vigorous nitration of Moskene, [2,6-dinitro-3-(tert -butyl)-4-(iso-prophyl)-toluene], with mixed acid and oleum at 115°(Ref 2). Its expl props were not investigated
*Refs:* 1)Beil-not found 2)M.S.Carpenter & W.M. Easter, JOC **19**, 100(1954) & CA **49**,3045(1955)

**N-Butyl-toluidine.** Same as N-Butyl-aminotoluene

**n-Butyl-4,4,4-trinitrobutyrate**, $(O_2N)_3C.CH_2.CH_2.COOC_4H_9$; mw 279.21, N 15.05%; liq, bp 107-8° at ca 0.4mm, $n_D$ 1.4550 at 20°. Was prepd from nitroform and n-butyl acrylate in n-butanolic soln, as described in Ref 2. Its expl props were not detd
*Refs:* 1)Beil-not found 2)US Rubber Co, Quarterly Progress Rept No 10, Contract Nord **10129**, Passaic, NJ(1950), 20

**2-Butyl-(1,1,1-trinitro-n-propyl)-ether,,**
$(O_2N).C.CH.CH_3$; mw 251.20, N 16.73%; liq; bp
$O.C_4H_9$
76° at 1mm, $n_D$ 1.4410 at 20°; was prepd by interaction of nitroform acetaldehyde(or paraldehyde) and n-butanol(Ref 2). Its expl props were not reported
*Refs:* 1)Beil - not found 2)US Rubber Co, Quarterly Progress Rept No 10, Contract Nord **10129**, Passaic, NJ(1950),p 8 and Table 1

### N-Butylurethane and Derivatives

**N-Butylurethane or Butylethylcarbamate**(called Butylurethan or Butyl-carbamidsäureäthylester in Ger), $C_4H_9.NH.COO.C_2H_5$; mw 145.20, N 9.65%. The Four isomers: *N-(n-Butyl)-urethane*(Ref 1); *N-(sec-Butyl)-urethane*(Ref 2); *N-(iso-Butyl) -urethane*(Ref 3); and *N-(tert-Butyl)-urethane* (Ref 4) are described in the literature
*Refs:* 1)Beil **4**,158 & (371) 2)Beil **4**, 162 & [636] 3)Beil **4**, 168 & [640] 4)Beil **4**,174 & (377)

**N-Nitroso-N-(n-butyl)-urethane**, $C_4H_9.N(NO).COO.C_2H_5$; mw 174.20, N 16.08%; red oil, bp-explodes when attempts are made to distill it; was prepd by nitrosation of N-(n-butyl)-urethane(Refs 1,2 & 3)
*Refs:* 1)Beil **4**,(372) 2)S.Nirdlinger & S.F.Acree, AmChem] **43**, 380(1910) & CA **4**, 1616-17(1910) 3)A.L.Wilds & A.L.Meader Jr, JOC **13**,771(1948)

**Mononitrobutylurethane**, $C_4H_9.N(NO_2).COO.C_2H_5$; mw 190.20, N 14.73%. Four isomers are described in the literature: *N-Nitro-N-(n-butyl)-urethane*, liq, fr p below -70°(Ref 1); *N-Nitro-N-(sec-butyl) -urethane*, liq, fr p below -70°(Ref 1); *N-Nitro-N -(iso-butyl)-urethane*, liq,fr p below -75°(Ref 1); and *N-Nitro-N-(tert-butyl)-urethane*, liq, bp 56° at 2mm(dec), d 1.051, $n_D$ 1.4331 at 20°; UV spectra detd(Ref 2); was prepd by nitrating N-(tert-butyl) -urethane with fuming $HNO_3$ & acetic anhydride (Ref 2). No expl props were reported for these nitro compds
*Refs:* 1)Beil **4**,159,163 & 172 2)H.M.Curray & J.P.Mason, JACS **73**, 5043-45 & 5449-50(1951); CA **46**, 9442(1952) & CA **47**,497(1953)

**Butylxylene and Derivatives**

*Butylxylene or Butyldimethylbenzene*(called Butyl-xylol or Butyl-dimethyl-benzol in Ger), $C_4H_9.C_6H_3(CH_3)_2$; mw 162.26, H 11.18%. Three isomers are described in Beil **5**,477,(213) & [339]

*Mononitrobutylxylene*, $C_4H_9.C_6H_2(NO_2)(CH_3)_2$; mw 207.26, N 6.7%. Two isomers are described in Beil **5**, 447 & [339]

**Dinitrobutylxylene**, $C_4H_9.C_6H(NO_2)_2(CH_3)_2$; mw 252.26, N 11.11%. Two isomers are known: *5-(tert-Butyl)-2,4-dinitro-m-xylene*, yel ndls(from alc), mp 68°; readily sol in org solvs(Refs 1,3 &4); and *5-(tert-Butyl-4,6-dinitro-m-xylene*, plates(from ligroin) or ndls(from alc), mp 84°(Refs 2 & 3). Other props & methods of prepn are given in the Refs listed

*Refs:* 1)Beil **5**, 447 & [339] 2)Beil **5**,448 3)A. Baur, Ber **33**, 2565-66(1900) 4)H.Barbier,Helv **11**,159(1928)

**2-Azido-5-(tert-butyl)-4,6-dinitro-m-xylene**, $C_4H_9.C_6(N_3)(NO_2)_2(CH_3)_2$, mw 293.28, N 23.88%; wh lfts with odor of musk(from alc), mp 146°; insol in w; sol in common org solvents. Can be prepd by the action of ammonia on the perbromide of diazotized 4,6-dinitro-2-amino-1,3-dimethyl-5-tert-butylbenzene. Its expl props were not detd

*Refs:* 1)Beil **5**, 448 & [340] 2)P.Fisch, La Parfumerie Moderne **12**, 129-33(1920) & ChZtr **93** II, 271(1922)

**Trinitrobutylxylene**, $C_4H_9.C_6(NO_2)_3(CH_3)_2$; mw 297.26, N 14.14%. The following isomers are known and described in the literature: *2,5,6-Trinitro-4-(n-butyl)-m-xylene*, ndls(from alc), mp 91°(Ref 4) (See also Refs 11 & 13); *2,5,6-Trinitro-4-(sec-butyl)-m-xylene*, ndls(from alc), mp 107°(Ref 4) (See also Refs 11 & 13); *2,4,6-Trinitro-5-(sec-butyl)-m-xylene*, fibers(from alc), mp 97°(Ref 4) (See also Refs 11 & 13); *2,5,6-Trinitro-4-(sec-butyl)-m-xylene*, ndls(from alc), mp 112°(Ref 4); and *2,4,6-Trinitro-5-(tert-butyl)-m-xylene*, ndls (from alc), mp 113°(stable form) and 105-6° (labile form)(Ref 1)(See also Refs 2,3,4,5,6,7,8,9, 10,11,12,13 & 14). Other props and methods of prepn are given in the Refs listed

Brnson(Ref 4) claimed that on treating 2,4,6-trinitro-5-(tert-butyl)-m-xylene with formaldehyde, it is possible to introduce two methylol groups which on nitration yields a *Dinitrate* deriv, $C_{12}H_{13}N_5O_{12}$ of possible value as component of proplnts and expls

*Refs:* 1)Beil **5**, 448,(213) & [340] 2)S.H.Katz and E.J.Talbert, BurMinesTechPaper **480**,37pp (1930) and CA **25**,547(1931) 3)D.V.Nightingale & L.I.Smith,JACS **61**,103(1939) & CA **33**,1681(1939) 4)H.A.Bruson, "Preparation of Polymers which Might Be of Intrest in Explosives", NDRC Div 8 Interim Rpt **PT-7**, p 25(1943) 5)C.J. Teahan, USP 2377727(1945) & CA **39**, 4092(1945) Teahan,USP 2377727(1945) & CA **39**,4092(1945) [Purification of trinitro-(tert-butyl)-m-xylene] 6)H.Brockmann & F.Volpers,ChemBer **80**,77-82 (1947) & CA **41**,3071(1947)(Chromatographic separation) 7)R.C.Fuson et al,JOC **12**,587(1947) & CA **41**,7386(1947)(Structure of musk xylene and others) 8)P.Fielding & R.J.W.LeFèvre, JCS **1950**,2812 & CA **45**,2775(1951)(UV spectra) 9)F. Carter,Perfumery & EssentOil Record **43**, 296,312 (1951) & CA **46**,1718(1952)(Pilot plant studies) 10)K.Kawasaki,Koryo(Aromatics) No **19**, 33-5 (1952) & CA **46**,7288(1952)(Methods of prepg various musks & musk derivs) 11)K.Kawasaki & K.Mihara, JSocOrgSyntheticChem(Japan) **10**, 259-63(1952) & CA **48**,11368(1954) 12)V.M. Rodionov et al, ZhObshchKhim **23**,1802-8(1953) & CA **49**,896(1955) 13)D.V.Nightingale & J.M. Shackelford,JACS **76**,5767-70(1954) & CA **49**, 14656(1955) 14)V.V.Serpinskii et al, ZhFizKhim **30**, 177-83(1956) & CA **50**, 10468(1956)(Vapor pressure data at RT)

**3-Butyn-1-yl-p-toluenesulfonate**, $HC{-}C(CH_3){=}CH$ / $HC{-}C{\equiv}CH$ ; $SO_2.O.CH_2.C{\equiv}CH$

mw 224.28, liq, bp 90° at $10^{-4}$mm; sl decopn at 128° & 0.01mm and expl decompn when distn was attempted at 0.5mm; $n_D$ 1.5262 at 19°; was prepd by slowly addg 3-butyn-1-ol ($HC{\equiv}C.CH_2.CH_2OH$) to a soln of toluene-p-sulfonyl chloride ($p\text{-}CH_3.C_6H_4SO_2Cl$) in pyridine at a temp below 25°

*Refs:* 1)Beil-not found 2)G.Eglinton & M.C. Whiting, JCS **1950**, 3653 & CA **45**,7053(1951)

**Butyramide and Derivatives**

*Butyramide, Butyric Amide or Butanamide*(called Butyramid, Buttersäureamid or Butanamid in Ger), $C_4H_9.CO.NH_2$; mw 87.12, N 16.08%. Two isomers are described in Beil **2**,275,293,(122,129), [251, 262] & {616,654}

**Azidobutyramide**, $C_4H_8N_4O$; 128.14, N 43.73%. Two isomers are known: *2-Azido-n-butyric-1-amide*, $CH_3.CH_2.CH(N_3).CO.NH_2$, ndls(from benz+ petr eth), mp 38-9°(dl-form) & ndls(from benz), mp 59°(l-form); and *2-Azido-iso-butyr-1-amide or 2-Azido-2-methyl-propion-1-amide*, $(CH_3)_2C(N_3).CO.NH_2$, rectangular pltlts, mp 93-4°. Other props & methods of prepn are given in Refs 1 & 2

*Refs:* 1)Beil **2**,287,299 2)M.D.Forster & R.

Müller, JCS **95** i, 194,196,197(1909)
*2-Nitroso-iso-butyramide,* $(CH_3)_2C(NO).CO.NH_2$; mw 164.16, N 17.07%; prisms(from boiling w), mp ca 158°(dec); was prepd by treating α-nitroso-iso-butyronitrile with concd HCl at 0°. Other props are given in the Refs 1 & 2
*Refs:* 1)Beil **2**,298 2)O.Piloty & B.G.Schwerin, Ber **34**,1865-66(1901) & JCS **80** I,516-17(1901)
*2-Nitro-iso-butyramide,* $(CH_3)_2C(NO_2).CO.NH_2$; mw 132.12, N 21.20%; lfts(from eth), mp 117-18°; mod sol in w or alc; less sol in eth; decompd by heating in dil $H_2SO_4$; other props & methods of prepn are given in Beil **2**,299 & (130)
*Dinitrobutyramide,* $C_3H_5(NO_2)_2.CO.NH_2$; not found in Beil or in CA thru 1956
**Trinitrobutyramide,** $C_3H_4(NO_2)_3.CO.NH_2$; mw 222.12, N 25.23%. An expl compd called *4,4,4(or γ)-Trinitrobutyramide,* $(O_2N)_3C.CH_2.CH_2.CO.NH_2$, was prepd by treating a methanolic soln of acrylamide with nitroform, as described in Ref 2; wh shiny plets(from water), mp 95-7°. It detonated relatively easily and burned vigorously
*Refs:* 1)Beil-not found 2)US Rubber Co Quarterly Progress Rept No 5, Contract Nord **10129**, Passaic, NJ(1948-49), 20-1

### Butyric Acid and Derivatives

**Butyric Acid,** *Butanoic Acid or Ethylacetic Acid* (called Buttersäure, Propan-carbonsäure or Äthylessigsäure in Ger), $C_3H_7.COOH$; mw 88.10, O 36.32%. Two isomers are known: *n(or α)-Butyric Acid,* $CH_3.CH_2.CH_2.COOH$ and *β(or iso)-Butyric Acid,* $(CH_3)_2CH.COOH$
*Refs:* 1)Beil **2**,264,288(115,126),[235,257] & {637} 2)Sax(1957),414 & 7, 6 3)CondChemDict (1961),190 & 623
**Azidobutyric Acid,** $C_4H_7N_3O_2$; mw 129.12, N 32.55%. The following isomers are known:
*2-Azido-butyric Acid,* $CH_3.CH_2.CH(N_3).COOH$, col ndls, mp 23.5°, expl mildly when thrown on a hot plate; bp 81° at 0.17mm, d 1.1519 at 33°; the liq rapidly attacks the skin(dl-form); its *Ag salt,* $C_4H_6N_3O_2Ag$, lustrous, transparent plates(from w), becomes violet on exposure to light; deflagrates when thrown on a hot plate; *2-Azido-butyric Acid* (l-form),pale yel oil; its *Brucine salt,* $C_4H_7N_3O_2 + C_{23}H_{26}N_2O_4 + 4H_2O$, col ndls(from w), mp 131°, dec on heating above mp(Refs 1, 4 & 6); *2-Azido-iso-butyric Acid or 2-Azido-2-methylpropionic Acid,*$(CH_3)_2C(N_3).COOH$, lustrous ndls, mp 31°, bp 75° at 0.15mm, expl mildly when thrown on a hot plate, d 1.1433 at 33°; it slowly produces irritating blisters on the skin; its *Ag salt,* $C_4H_6N_3O_2Ag$, col ndls(from w), detonates when thrown on a hot plate(Refs 2 & 4); and *4-Azido-butyric Acid,* $N_3.CH_2.CH_2.CH_2.COOH$, yel oil, fr p below 0°, bp 135° at 11mm; readily sol in alc or eth; less sol in w; its *Na salt,* $C_4H_6N_3O_2Na$, crysts(from dil alc), dec ca 205°(Refs 3 & 5). Other props & methods of prepg azidobutyric acids are given in the refs listed
These isomers form liq, *Azidobutyryl Ethyl Esters,* $N_3.C_3H_6.CO_2.C_2H_5$
*Refs:* 1)Beil **2**,287 & [257] 2)Beil **2**,299 3)Beil **2**,(126) 4)M.O.Forster & R.Müller, JCS **95 I,** 193,195 & 196(1909) 5)T.Curtius & W. Giulini,Ber **45**,1047 & 1048(1912); JCS **102 I,** 427(1912) & CA **6,** 2433(1912) 6)W.F.Huber,JACS **77,** 112(1955) & CA **50**,804(1956)
**Butyric Acid Azide or Butyryl Azide,** $C_3H_7.CO.N_3$; mw 113.12, N 37.15%. Only one isomer is known: *iso-Butyryl Azide,* $(CH_3)_2CH.CO.N_3$, wh cottagecheese like ppt, very unstable even in its ethereal soln; the freshly prepd compd decomposes vigorously with evolution of gas when heated in a tube; was prepd by treating iso-butyri hydrazide with HCl & a $NaNO_2$ soln cooled with ice(Refs 1 & 2)
*Refs:* 1)Beil **2**,{656} 2)T.Curtius & O.Hambsch, JPraktChem **125**,185(1930) & BrA **1930A**,755-56
**4-Azidobutyryl Azide,** $N_3.CH_2.CH_2.CH_2.CO.N_3$; mw 154.14, N 54.53%; yel oil, bp-expl when heated; was prepd by the reaction of the hydrochloride of 4-azidobutyryl hydrazide with $NaNO_2$ & $H_2SO_4$ in the presence of ether(Refs 1 & 2)
*Refs:* 1)Beil **2**,(126) 2)T.Curtius & W.Giulini,Ber **45**,1049(1912) & JCS **102** I,427(1912)
**Butyric Acid Hydrazide or Butyryl Hydrazide,** $C_4H_{10}N_2O$; mw 102.14, N 27.43%. Two isomers are known: *n-Butyryl Hydrazide,* $C_3H_7.CO.NH.NH_2$, wh hygr ndls, mp ca 44°, bp 138° at 20mm & 120° at 10mm; readily sol in w, alc or eth; it forms a *Hydrochloride salt,* $C_4H_{10}N_2O \cdot HCl$, wh crysts, mp 148°(Ref 1); and *iso-Butyryl Hydrazide,* $(CH_3)_2CH.CO.NH.NH_2$, wh ndls(from eth-alc) or lfts(thru sublimation), mp 104; readily sol in w or alc; sl sol in boiling eth; it forms a *Hydrochloride salt,* crysts, mp 122°, very hygr; and a *Picrate salt,* $C_4H_{10}N_2O \cdot C_6H_3N_3O_7$, yel ndls(from w), mp 144°(Ref 2)
See also Refs 3 & 4 for methods of prepg butyryl hydrazides
*Refs:* 1)Beil **2**,276 2)Beil **2**,294 & {656} 3)K. Satake & T.Seki, Kagaku no Ryôiki(JJapChem) **4**, 557(1950) & CA **45**,4604(1951) 4)C.Ainsworth, JACS **76**,5774(1954) & CA **49**,14639(1955)
**4-Azidobutyryl Hydrazide,** $N_3.CH_2.CH_2.CH_2.CO.$-

$NH.NH_2$; mw 143.15, N 48.93%; yel gelatinous mass; was obtd by adding HCl to a cooled ethereal soln of isopropylidene-4-azidobutyryl hydrazide; the latter prepd by warming hydrazine hydrate with 4-azidobutyric acid ethyl ester followed by treating with acetone
*Refs:* 1)Beil **2**,(126) 2)T.Curtius & W.Guilini,Ber **45**,1049(1912)

**Mononitrobutyric Acid,** $C_4H_7NO_4$; mw 133.10, N 10.52%. Only one isomer is described in the literature: *2-Nitro-iso-butyric Acid or 2-Nitro-2-methylpropionic Acid,* $(CH_3)_2C(NO_2).COOH$, crysts, mp 95°; readily sol in alc or eth; mod sol in hot chlf; sl sol in w; v sl sol in $CS_2$; dec on prolonged heating & by heating with w, xylol or nitrobenzene it forms a blue oil(Refs 1 & 2). Other props & methods of prepn are given in the
*Refs:* 1)Beil **2**,(129) & {662} 2)W.Steinkopf & A.Supan,Ber **44**, 2893,2896(1911)

**Dinitrobutyric Acid,** $C_4H_6N_2O_6$; mw 178.10, N 15.73%. The dinitro derivs of butyric acid were not found described in the literature. Klager(Ref 2) prepd & described the *aci-Na salt of Methyl-4,4-dinitrobutyrate,* $O_2N.\overset{NO_2Na}{\overset{\|}{C}}.CH_2.CH_2.COOCH_3$, bright yel crysts; and the *Di-Na salt of 4,4-Dinitrobutyrate,* $O_2N.\overset{NO_2Na}{\overset{\|}{C}}.CH_2.CH_2.COONa$, yel crysts(from MeOH), mp 97°(dec). Later, Klager(Ref 2) patented the prepn of the *Na salts* of methyl, ethyl & butyl esters of *4,4-dinitrobutyric acid.* These and other Na salts of poly nitro compds or nitrated new aliphatic compds were proposed as expl ingredients because of their uniformity & relative stability
*Refs:* 1)Beil-not found 2)K.Klager, JOC **16**, 162-3(1951) & CA **45**, 6576(1951) 3)K.Klager, USP 2640072(1953) & CA **48**,7626-27(1954)

**Trinitrobutyric Acid,** $C_4H_5N_3O_8$; mw 223.10, N 18.83%. Its isomer *4,4,4(or γ)-Trinitrobutyric Acid,* $(O_2N)_3C.CH_2.CH_2.COOH$, wh ndls, mp 62-3°, was prepd at the lab of US Rubber Co(Ref 2) by refluxing a suspension of 4,4,4-trinitrobutyramide, $(O_2N)_3C.CH_2.CH_2.CO.NH_2$ in aq HCl. It was also prepd by Dacons as described in conf Ref 3. The expl props of trinitrobutyric acid are not described in Ref 2. Its *silver slat,* prepd by treating the acid with Ag nitrate(Ref 2) is a mild expl, fairly insensitive to friction
*Refs:* 1)Beil-not found 2)US Rubber Co, Quarterly Progress Rept No 7, Contract Nord **10129**, Passaic, NJ(1949), 10 3)J.C.Dacons et al, "Improved 'One Pot' Processes for Preparation of 4,4-Dinitropimelic Acid and 4,4,4-Trinitrobutyric Acid", NavOrdRept **4437**(1956)(Cong, not used as a source of info)

**Trinitrobutyric Acid, Derivatives.** The *Methyl Ester,* $(O_2N)_3C.CH_2.CH_2.CO.CH_3$, mw 237.13, N 17.72%, is col liq, bp 101-3 at 2mm, $n_D$ 1.4592 at 20° which burns rapidly in a flame. It was prepd by interaction of nitroform and methyl acrylate(Ref 1). Ville(Ref 3) prepd an explosive compd *Trinitroethyltrinitrobutyrate*(TNEtBu), $(O_2N)_3C.CH_2.CH_2.COO.CH_2.C(NO_2)_3$; mw 386.16, N 21.76%, mp 93-4°, by interaction of trinitrobutyryl chloride, $(O_2N)_3C.CH_2.CH_2.COCl$ with trinitroethanol, $HO.CH_2.C(NO_2)_3$ in anhydrous benzene with small amt of concd $H_2SO_4$. Expl & other props of TNEtBu are described in conf Ref 2
*Refs:* 1)US Rubber Co, Quarterly Progress Rept No 4, Contract Nord **10129**(1948), 6-7 2)O.E. Sheffield,"Properties of Explosives of Military Intrest", PATR **1740**, Suppl No 1(1958), 459-63 (Conf)(Not used as a source of info) 3)J.Ville, MP **42**, 25-6(1960)

**Butyric Acid Azide.** Same as Butyryl Azide

**Butyric Amide.** Same as Butyramide

**Butyric Anhydride**(called Buttersäureanhydrid in Ger), $C_8H_{14}O_3$; mw 158.19, O 30.34%. Two isomers are described in the literature: *N-Butyric Anhydride,* $(CH_3.CH_2.CH_2.CO)_2O$, clear liq, fr p -75°, bp 199.5°, flash p 190°F(CC), d 0.9681 at 20°; other props & methods of prepn are given in Refs 1,3,4,5,6 & 7; and *iso-Butyric Anhydride,* $[(CH_3)_2CH.CO]_2O$, liq, fr p ca 56.4°, boiling range 180-87°, d 0.951-0.956 at 20°; other props & methods of prepn are given in Refs 2 & 7. These compds are used in the synthesis of various butyrates, drugs and tanning agents
*Refs:* 1)Beil **2**,274,(122) & [251] 2)Beil **2**, 292,(128),[262] & {653} 3)G.E.Smith & W. Hunter,BritP 606607(1948) & CA **43**,3839(1949) 4)H.J.Hagemeyer Jr, USP 2476859(1949) & CA **43**,8398(1949) 5)G.E.Smith & W.Hunter, USP 2492403(1949) & CA **44**,4925(1950) 6)Sax(1957), 414 7)CondChemDict(1961),190,623

**Butyrolactone - α - carbonyl Azide**(called Butyrolacton-α-carbonsäure-azid in Ger), $CH_2.CH_2.\overset{O\text{———}CO}{\overset{|}{\underset{|}{CH}}}.CON_3$; mw 155.11, N 27.09%; yel oil, expl violently when heated rapidly; was prepd by the action of $HNO_2$ on butyrolactone-α-carboxylic acid(Ref 2)
*Refs:* 1)Beil-not found(The parent compd,

butyrolactone-α-carboxylic acid, is described in Beil **18**, 370) 2)T.Curtius & H.Sauerberg, JPraktChem **125**,141,147(1930) & CA **24**,3215(1930)

**Butyrone, Dipropyl Ketone or 4-Heptanone** [called Heptanon-(4), Dipropylketon or Butyron in Ger], $C_3H_7.CO.C_3H_7$; mw 114.18, O 14.01%; col liq, fr p -32°, bp 144°, flash p 49°, d 0.8162 at 20°, $n_D$ 1.4068 at 20°(Refs 1,2 & 3). Other props & methods of prepn are given in the Refs. It is used as a solv for NC, raw & blown oils, resins & lacquers(Ref 3)
*Refs:* 1)Beil **1**, 699(359),[754] & {2857} 2)Sax (1957),409 3)CondChemDict(1961,415

### Butyronitrile and Derivatives

*Butyronitrile, Butanenitrile or Propylcyanide* (called Butyronitril, Butannitril or Propylcyanid in Ger), $CH_3.CH_2.CH_2.CN$; mw 69.10, N 20.27%; col liq, fr p -112.6°, bp 116-118°, d 0.0796; sol in alc or eth; sl sol in w; other props & methods of prepn are given in Ref 1. It is used as a basic material or intermediate for industrial chemicals or pharmaceutical products(Ref 2)
*Refs:* 1)Beil **2**,275,(123), [252] & {618} 2) CondChemDict(1961),191
**4-Azido-butyronitrile,** $N_3.CH_2.CH_2.CH_2.CN$; mw 110.12, N 50.88%; liq, bp 55-60° at 5mm; was prepd by heating 4-chloro-butyronitrile with $NaN_3$; when this compd is treated with chlorosulfonic acid($ClSO_3H$) in chlf or with concd $H_2SO_4$ in $CCl_4$ at 20-40°, *Trimethylenetetrazole* is formed (Refs 1 & 2)
*Refs:* 1)Beil **2**,{636} 2)C.Gyógyszer, GerP 611692(1934) & CA **29**, 5994-95(1935); USP 2020937(1934) & CA **30**,575(1936)
**2-Nitroso-iso-butyronitrile or 2-Nitroso-2-methyl -propane-1-nitrile,** $(CH_3)_2C(NO).CN$; mw 98.10, N 28.56%; col solid, mp-begins to dec at 53° turning to a dk blue liq, and at 80° it evolves col gas & deposits crysts; was obtd by the oxidn of α-hydroxylamino-iso-butyronitrile with Cl water at 0°(Refs 1 & 3) or by treating α,α'-azoxy -isobutyronitrile with $SnCl_2$ in concd HCl at 20-25°(Refs 2 & 4)
*Refs:* 1)Beil **2**,298 2)Beil **2**, {662} 3)O.Piloty & B.G.Schwerin, Ber **34**,1864,(1901) & JCS **80** I, 516-17(1901) 4)J.G.Aston & G.T.Parker, JACS **56**, 1387-88(1934)
**Mononitrobutyronitrile,** $C_4H_6N_2O_2$ mw 114.10, N 24.55%. The following isomers are known:
*3-Nitro-butyronitrile,* $CH_3.CH(NO_2).CH_2.CN$, straw colored liq, bp 81-2° at 0.5mm; was prepd by reaction of 2-nitroprop-1-ene with an aq soln of KCN(Refs 3 & 7); *4-Nitro-butyronitrile,* $O_2N.CH_2.CH_2.CH_2.CN$, col liq, having sl odor & sharp sweet taste; bp 236°(dec), 160° at 35mm or 118-21° at 3mm; readily sol in alc, eth, chlf or alkalies; insol in w; was prepd from 4-iodo-butyronitrile and $AgNO_3$ or by other methods(Refs 1 & 6); *2-Nitro-isobutyronitrile or 2-Nitro-2-methyl -propion-1-nitrile,* $(CH_3)_2C(NO_2).CN$, ndls(from ligroin), mp 35°, bp 97° at 45mm or 73° at 12mm; dec at 110-12°; readily sol in alc, sl sol in w; was obtd from 2-nitroso-iso-butyronitrile by remaining in a wet condition or by treating with concd $HNO_3$; and by treating α-hydroxylamino -iso-butyronitrile with a sulfuric acid-$KMnO_4$ soln at 30°(Refs 2 & 5); and *3-Nitro-iso-butyronitrile, 3-Nitro-2-methyl-propion-1-nitrile or 3-Nitro-2-cyano-propane,* $O_2N.CH_2.CH(CH_3).CN$, liq, bp 68-70° at 0.5mm; was prepd by adding 1-nitroprop-1-ene in alc to an aq soln of KCN at -5 to 0°(Refs 4 & 7)

These compds are useful as intermediates in the manuf of expls, dyes & pharmaceuticals
*Refs:* 1)Beil **2**,287 & {636} 2)Beil **2**,299 & (130) 3)Beil **2**, {636} 4)Beil **2**, {662} 5)W.Steinkopf & A.Supan, Ber **44**,2895(1911) 6)O.Wulff et al, GerP 728531(1940) & CA **38**,376(1944) 7)G.D. Buckley et al, JCS **1947**,1501,1502; USP 2428614(1947) & CA **42**,770(1948)
*Dinitrobutyronitrile,* $C_4H_5N_3O_4$; not found in Beil or in CA thru 1960
**Trinitrobutyronitrile,** $C_4H_4N_4O_6$; mw 204.10, N 27.45%; not found in Beil or in CA thru 1960. The attempted prepn of *4,4,4-Trinitrobutyronitrile,* $(O_2N)_3.C.CH_2.CH_2.CN$, is described in Conf Aerojet Rpt **330**(1948),p 64. See also K.S.Warren, Doctoral Thesis, Purdue Univ(1947)

### Butyrophenone and Derivatives

*Butyrophenone, Butyrylbenzene, Phenylbutanone or Propyl Phenyl Ketone* [called Butyrophenon, Butyrylbenzol, 1-Oxo-1-phenyl-butan, 1-Phenyl -btuanon-(1) or Propylphenylketon in Ger], $CH_3.CH_2.CH_2.CO.C_6H_5$; mw 148.20, O 10.80%; col liq, fr p 11°, bp 228-229.5° at 760mm, d 0.9967 at 25°; other props & methods of prepn are given in Beil **7**, 313,(166) & [241]
**Mononitrobutyrophenone,** $C_2H_5.CH_2.CO.C_6H_4.NO_2$; mw 193.20, N 7.25%. The *2'-Nitro deriv,* lt yel oil having a sweet odor resembling that of NB, vol with steam; and the *3'-Nitro deriv,* wh brittle plates(from alc), mp 61°; both were prepd by Morgan & Hickinbottom(Ref 2) and listed in Beil(Ref 1). The *4'-Nitro deriv,* crysts, mp 66-67°, was prepd by Sugimoto et al(Ref 3)

*Refs:* 1)Beil **7**, [242] 2)G.T.Morgan & W.J. Hickinbottom, JCS **119** II, 1882-83(1921) 3)N. Sugimoto et al, JPharmSocJapan **71**,1161(1951); CA **46**,5011(1952) & JapP 1482(1954); CA **49**, 11707(1955)

**Mononitro-diazobutyro-phenone,** $C_{10}H_9N_3O_3$; mw 219.20, N 19.17%. The isomer, *4'-Nitro-2-diazo -butyrophenone or 4-Nitro-α-diazo-butyrophenone,* [called 1-p-Nitrobenzoyl-1-diazopropane by Wilds & Meader(Ref 2)] $C_2H_5.C(N_2).CO.C_6H_4.NO_2$, yel ndls(from petr eth), mp 97.5-98.5°(dec); sol in AcOH with evoln of N; was prepd by reacting diazopropane in eth at -20° with p-nitrobenzoyl chloride(Ref 2), The same compd can be prepd by the method described by Eistert(Ref 3).

*Refs:* 1)Beil-not found 2)A.L.Wilds & A.L. Meader Jr, JOC **13**, 774(1948) & CA **43**,4653(1949) 3)B.Eistert,AngChem **61**,186(1949) & CA **43**, 6178(1949)

**Butyryl Azide.** See under Butyric Acid

**Butyryl Hydrazide.** See under Butyric Acid

**Butyrylhydroperoxide.** (Perbutyric or Peroxybutyric acid)(called Butyrylhydroperoxyd or Perbuttersaure in Ger), $CH_2H_5.CH_2.CO.O.OH$; mw 104.10, O 46.11%; liq, fr p -10.5° bp 26-3° at 12mm(72% concn) & 41-2° at 13mm(85-90% concn); expl on sl heating; was prepd by reacting butyric anhydride with an excess of $H_2O_2$ in the presence of $H_2SO_4$(Refs 1 & 2). Other methods of prepn & props are given in Refs

*Refs:* 1)Beil **2**,(122),[215] & {613} 2)J.D.'Ans W.Frey,Ber **45**, 1850,1852,(1912; CA **6**,2737-38 (1912) & JCS **102** I, 601-2(1912) 3)F.Fichter & H.Reeb,Helv **6**, 456(1923) & CA **17**,3323(1923) 4)F.Fichter & A.Burgin,Helv **14**,100(1931)

**Butyryl Nitrate**(called Butyrylnitrat or Saltpetersäure-buttersäure-anhydrid in Ger), $CH_3.CH_2.CH_2.CO.ONO_2$; mw 133.10, N 10.52%; lt yel liq, mp -detonated when heated; was prepd by reaction of butyryl chloride with $AgNO_3$ at low temp(Refs 1 & 2)

*Refs:* 1)Beil **2**, 274 2)F.E.Francis, Ber **39**,3800 (1906) & JCS **92** I, 53(1907)

**Butyryl Nitrite**(called Butyrylnitrit or Salpertigsäure-buttersäure-anhydrid in Ger), $CH_3.CH_2.CH_2.CO.ONO$; mw 117.10, N 11.96%; yel liq, bp -dec on heating between 70-80°; was prepd by action butyryl chloride on $AgNO_2$ at 30-40°(Refs 1 & 2)

*Refs:* 1)Beil **2**,(122) 2)E.Ferrario,Gazz **40** II, 99(1910) & JCS **98** I, 707(1910)

**Butyryl Peroxide.** Same as Dibutyryl Peroxide

**BUU.** A cast double-base proplnt for rocket motors. The prepn & props are described in conf "Propellant Manual", SPIA/M2(1961),Unit No 619

**Buxton Test.** A gallery test for "Permitted" expls conducted between WWI & WWII at Buxton, England

*Ref:* Marshall **3**(1932),186-7

**Buzane.** Same as Bihydrazine

**Buzylene**(Buzylen in Ger). This term has, according to Ref 4, two meanings: a) The bivalent radical - N:N.NH.NH- and b)An unisolated azohydroxylamine compd, $HN{:}N.NH.NH_2$, called isotetrazene or diazohydrazine. It has been claimed that isotetrazene occurs in hippuryl phenyl-buzylene, $C_6H_5.N{:}N.NH.NH.CO.CH_2NH.CO.C_6H_5$(Refs 2,3,4)

According to Hofmann et al(Ref 3), the buzylene group is the same as the tetrazene group

*Refs:* 1)Beil-not found 2)T.Curtius,Ber **26**,1266 (1893) 3)K.A.Hofmann et al,Ber **93**,1087(1910) 4)Hackh's(1946),152

**Buzz Bomb.** See Bombs, Buzz in this volume

**BV-143.** A Ger WWII guided subsonic missile of the air-to-surface type

*Ref:* DictGuidedMissiles(1959),106

**BV-246.** A Ger WWII guided missile of the air-to-surface type

*Ref:* DictGuidedMissiles(1959),106

**BW.** Abbr for Biological Warfare. See under Chemical, Biological and Radiological(CBR) Warfare

**BWC.** Brit abbr for "board wood cellulose" which is obtained from Pinus Radiata. It contains ca 85% of α-cellulose

*Ref:* H.A.Aaronson,Dover, NJ; private communication(1960)

# C

**C**(Explosifs)(Explosifs de mine type C). Mining expls manufd in France beginning ca 1895 and designated in Fr as: a) **n°1a**: AN 93 & Amm cresylate 7% b) **n°1b**: AN 78 & Amm cresylate 22% and c) **n°2**: AN 75 & Amm cresylate 25%
*Refs:* 1)A,Delatour,MP **10**,57(1899–1900) 2)Daniel(1902),90

**C**(Explosives). See Composition C,C-2, C-3 and C-4

**C**(Powder). A "coarse"(large grain) BkPdr formerly manufd by DuPont Co. Also CC and CCC Powders
*Ref:* Daniel(1902),90

**C**(Process). See "C" Process (Croning Process of Precision Casting)

**$C_1$**(Poudre). A Fr BkPdr formerly used in field guns
*Ref:* Daniel(1902),90

**C-2.** A Ger guided missle of WWII, known as Wasserfall
*Ref:* Anon,"Germam Explosive Ordnance",TM **9-1985-2**(1953),219-23

**$C_2$**(Explosive). According to Schwartz(Ref), it is a substance, closely related to TNT, with an oily base. Workers exposed to $C_2$ regularly developed severe headache, nausea, vomitting and occasional tremors of the upper extremities within a few hours after exposure
*Ref:* A.M.Schwartz,NewEnglJMed **235**,541 (1946) & CA **41**,285(1947)

**C-2**(Polvere). An Ital proplnt which was manufd since ca 1910 by the Società Italiana Dinamite Nobel Avigliana. The compn used during WWII contd NC(mixt of collodion and guncotton) 70, NG 24, vaselin 5 & Na carbonate(or bicarbonate) 1%. ( See also CSP-2)
*Ref:* Anon, Ordnance Sergeant,Aug 1943,p 17

**$C_2$**(Poudre). A Fr BkPdr formerly used in Naval 65 and 90mm guns
*Ref:* Daniel(1902),90

**C6.** A Ger expl compn of WWII used as a substitute for TNT
*Ref:* PATR **2510**(PB 161270)(1958),p Ger 23

**C-44.** An experimental double-base proplnt prepd and investigated at CALTECH,Pasadena, Calif, during WWII: NC(12.6%N) 56.0,NG 43.0 & EtCentr 1%
*Ref:* L.Pauling et al, OSRD Rept **5967**(1945), 11

**C/68.** An older Ger BkPdr, prismatic, with 7 perforations and of low d

**C/75.** An older Ger BkPdr, prismatic, with 1 perforation and high d

**C/77.** An older Rus BkPdr, prismatic, with 7 perforations and of low d
*Ref:* Daniel(1902),651

**C/88.** A Ger designation for PA, which was used for some time, beginning in 1888, for filling projectiles
*Ref:* Daniel(1902),90

**C/89.** A Ger designation for a double-base proplnt similar in compn to an Italian Ballistite. It was also known as RGP/89 (Rauchloses Geschützpulver,1889, which means Smokeless Gunpowder,1889)
*Ref:* Daniel(1902),90-2

**C-509 Propellant.** See conf Report by R.A.Miller & J.E.Baldwin, NOTS(Naval Ordnance Test Station) TP **2660**(1962)

**$CA_1$**(Coton azotique 1)(Fr). Collodion cotton contg ca 12%N and designed for use in varnishes

**$CA_2$**(Coton azotique 2)(Fr). Collodion cotton contg ca 12%N and designed for use in Blasting Gelatin(Dynamite gomme in Fr)
*Ref:* M.M.Kostevitch, Buenos Aires. Private communication(1955)

**Cacao(or Cocoa)Powder.** See Brown Powder under Black Powder Modifications

**Cacodyl Cyanide or Dimethylarsenocyanide,** $(CH_3)_2As.CN$; crysts, mp 36.5–37.5°. This extremely toxic compd was first prepd by Bunsen(Ref 1). Expln of cacodyl cyanide cost Bunsen the sight of his right eye(Ref 2)

*Ref:* 1)Beil **4**,608 & [988] 2)F.J.Moore, "A History of Chemistry", McGraw-Hill, NY (1939), 267

**CAD.** Abbr for Cartridge Actuated Device

**Cadaverine and Derivatives**

*Cadaverine; 1,5—Diaminopentane; 1,5 -Pentanediamine or Pentamethylenediamine,* $H_2N.(CH_2)_5.NH_2$; syrup, mp + 9°. Other props & prepn are in Beil **4**, 266, (421) & [708]

**3,3-Dinitrocadaverine or 3,3-Dinitro-1,5 -pentanediamine,** $H_2N.CH_2.CH_2.C(NO_2)_2.CH_2-CH_2.NH_2$; mw 192.18, N 29.16%; col crysts which become yel on exposure to the atm, mp 76-9°; was obtained by mechanically shaking 3,3-dinitrocadaverine dihydrochloride with the theoretical amt of std NaOH soln for 1hr. The dihydrochloride was obtained by refluxing dimethyl-3,3-dinitropentadicarbanate with concd HCl for 16hrs. Expl props of dinitrocadaverine were not detd

*Ref:* 1)Beil—not found 2)L.Herzog et al, JACS **73**, 751(1951) & CA **45**, 5609(1951)

*Note: Trinitro-,* $C_5H_{11}N_5O_6$ *Tetranitrocadaverine,* $C_5H_{10}N_6O_8$ were not found in Beil or CA thru 1956

**Cadmium,** Cd, at wt 112.4; soft blue-wh malleable metal or grayish-wh powd; d 8.642 at 17°, mp 320.9°, bp 767°; insol in w; sol in acids and AN solns; occurs chiefly as greenockite (CdS) associated with Zn(or Pb) manuf. Its toxicity is discussed by Sax(Ref 3). Fire and expln hazards are slight when Cd dust is exposed to heat or flame(Ref 3)

Cd and some Cd salts were patented by DeMent for use in smoke-producing pyrotechnic compns (Ref 6)

*Refs:* 1)Mellor **4**(1923),420,457 & 472 2)Kirk & Othmer **2**(1948),716-23 3)Sax(1957),417 4)Gmelin,Syst Nr **33**(1959) 5)CondChemDict(1961),193 6)J.DeMent, USP 2995526(1961)

**Cadmium Acetylide.** See Vol 1,p A71-L

**Cadmium Amide.** See Vol 1,p A169-L

*Note:* According to Jacobson **2**(1948),17, $Cd(NH_2)_2$ expl on rapid heating above its mp(180°)

**Cadmium Azide.** See Cadmium Diazide in Vol 1,p A526-L

**Cadmium Azidodithiocarbonate.** See Vol 1,p A636-R

**Cadmium Bromate.** See under Bromates

**Cadmium Chlorate.** See under Chlorates

**Cadmium Diammine Azide.** See Vol 1, p A277,table A, item Cd 1

**Cadmium Diazide.** See Vol 1,p A526-L

**Cadmium Fulminate.** See under Fulminates

**Cadmium Hexammine Bromate.** See Vol 1, p A277,table A, item Cd 5

**Cadmium Hexammine Chlorate.** See Vol 1, p A277, table A, item Cd 6

**Cadmium Hexammine Perchlorate.** See Vol 1, p A277,table A, item Cd 7

**Cadmium Hydrazine Nitrate,** $Cd(NO_3)_2.3N_2H_4$; wh crysts, expl on rapid heating to ca 250° or on strong impact; when spread in a thin layer it burns with evoln of brn fumes; can be prepd by treating an aq (or alcoholic) soln of Cd nitrate with redistilled hydrazine hydrate, free of ammonia

*Ref:* L.Médard & J.Barlot,MP **34**,161-4(1952) & CA **48**,6125(1954)

**Cadmium Iodate.** See under Iodates

**Cadmium Nitrate.** See under Nitrates

**Cadmium Nitride.** See under Nitrides

**Cadmium Perchlorate.** See under Perchlorates

**Cadmium Permanganate.** See under Permanganates

**Cadmium Picrate.** See under Picrates

**Cadmium Selenide.** See under Selenides

**Cadmium Sulfide.** See under Sulfides

**Cadmium Tetrammine Bromate.** See Vol 1, p A277, item Cd 2

**Cadmium Tetrammine Chlorate.** See Vol 1, p A277, item Cd 3

**Cadmium Tetrammine Iodate.** See Vol 1, p A277, item Cd 4

**Caesium.** See Cesium

**Caffeine and Derivatives**

*Caffeine or 1,3,7-Trimethyl-xanthine*(Kaffein in Ger), $C_8H_{10}N_4O_2$; mw 194.19, N 28.85%; col crysts, mp of anhydrous compd 234-5°. Other props and prepn in Beil **26**, 461, (136) & [266]

**8-Azidocaffeine or 1,3,7-Trimethyl-8-azido-xanthine,** $C_8H_9N_7O_2$; mw 235.21, N 41.69%; col ndls(from alc), mp dec w/o melting; v sl sol in w; was prepd by treating an aq soln of 8-hydrazinocaffeine hydrochloride with Na nitrite. Its expl props were not reported

*Refs:* 1)Beil **26**, 477 2)L.Cramer, Ber **27**, 3090(1894) 3)CA 1907-50, not found

*8-Nitrocaffeine or 1,3,7-Trimethyl-8-nitro-xantine,* $C_8H_9N_5O_4$, mw 239.19, N 29.28%; yel lfts(from w). Other props & prepn in Beil **26**, 477

**Cahuecit.** See Carboazotine

**Cahücit.** Ger name for Cahuecit. See Carboazotine

**Cake**(Galette in Fr). The term galette is used by the French in the manuf of BkPdr and smokless proplnts. The galette of BkPdr is described by Pascal(Ref 1) and it is essentially the same as the "press-cake", described by Davis(Ref 3)

In the manuf of Fr smokless proplnts there are essentially two kinds of galettes. When intended for the manuf of single-base(NC) proplnt, the galette consists of pulped, stabilized NC(coton-poudre in Fr) impregnated with w or alc and compressed in a hydraulic press. The resulting galette, which is similar to the Amer *block*, is broken up and blended with a colloiding agent(such as ether-alc or acetone) and a stabilizer(such as DPhA) in an apparatus called "malazeur"(mixer or blender)

When intended for use in the manuf of double-base solventless proplnts("poudres sans dissolvant", abbreviated as poudres SD), the galette consists of a mixt of NC & NG(w/wo DEGDN which is called Néo in Fr), impregnated with w and compressed in a hydraulic press. For example, "galette 2-SD" consists of $CP_2SD$ (coton-poudre with N 11.7%) ca 72.7 & NG ca 27.3% impregnated with w. This galette is broken up and blended in a "malaxeur" with stabilizers -gelatinizers and other ingredients of proplnts. For example, the so-called "poudres épaisses"SD-12, SD-19 & SD-21 contain: galette 2-SD ca 91, EtCentr 8.50-8.75 & vaselin 0.25-0.50% with 0.1% graphite added(Refs 2,4 & 5)

Lhoste(Ref 6) and Parpaillon(Ref 8) described rapid methods of analyses of various galettes and Miaud(Ref 7) described a method of detn of moisture content in galettes SD and in woodpulps by means of high-frequency currents

*Refs:* 1)Pascal(1930),204-5 2)J.Chédin,MP **29**, 95-110(1939) 3)Davis(1943),46-7 4)G.Fleury,MP **30**,236(1948) 5)A.Douillet,MP **30**,303(1948) 6)P. Lhoste,MP **37**,149(1955) 7)P.Miaud,MP **37**,465 (1955) 8)M.Parpaillon,MP **40**,217(1958)

**Cake Powder,** also called *Mammoth* or *Rodman Powder.* See under BLACK POWDER or GUNPOWDER, Historical

**Caking(or Agglomeration)and Its Prevention.** Caking is defined in Hackh's(1944),p 156, as "the transformation of a powdered substance into a solid mass either by moisture, heat or pressure". The most common method of preventing caking of a hygroscopic substance is coating its particles with non-hygroscopic materials. Several methods and Refs on waterproofing AN crystals are given in Vol 1,pp A334-L to A335-R under AMMONIUM NITRATE

Following are some addnl Refs on prevention of caking: 1)A.Scott,USP 1811699(1939) & CA**25**,5033(1931)(Caking of cryst substances such as used in chlorate expls can be prevented by incorporating asbestos 5% or less of total wt) 2)Dynamit A-G,GerP 722144(1942) & CA **47**, 5241(1943)(Caking of AN expls can be prevented by incorporating a small quantity of voluminous alumina hydrate) 3)R.C.Clogau, USP 2407151 (1946) & CA **41**,286(1947) [Caking of AN, Na nitrate or other $H_2O$-sol granular materials can be prevented by coating the grains with a finely divided(less than 1$\mu$ in diam) Si compds (such as $CaSiO_4$ or pptd $SiO_2$) in amts of 0.5-5%] 4)J.Ordonneau, AnnMines(France) **139**,35-63(1950) & CA **44**,6587(1950)(Caking of KCl crysts can be

reduced by coating them with paraffin waxes and high-boiling petroleum fractions) 5)"Montecatini"SGIMC,ItalP 455258(1950) & CA **45**,5352 (1951)(Caking of hygroscopic materials, such as AN or kieselguhr can be prevented by coating their particles with $H_2O$-repellant substances, such as naphtha, melted paraffin or methyl chlorosilanes) 6)T.V.Zabolotskii,ZhPriklKhim **23**, 1203-8(1950) & CA **46**,8817(1952)(Caking of AN is attributed to a polymorphic change at 32° to a less-dense crystal structure and the sorption of w to form a satd soln on the surface from which fine crysts separate by evapn to fill intercryst spaces. The 1st cause can be eliminated by the addn of foreign salts, particularly $MgCl_2 6H_2O$, to the soln from which AN is being crystd. When present in a concn of 3% of that of the AN, the Mg salt is partly absorbed into the crystal lattice of the AN and forms rounded rather than needle-like crysts and eliminates transition at 32°. When this is followed by coating with a soln of paraffin in anthracene oil to the extent of 0.4-0.5%, the caking is eliminated) 7)Y.Venkatesham, IndianP 41936(1951) & CA **46**,1692(1952)(Caking of AN can be prevented by mixing it with powd groundnut oil cake) 8)W.H.Rinkenbach,USP 2660541 (1953) & CA **48**,2301-2(1954)(Caking of water-sol salts can be partially prevented by coating the particles with a thin layer of water-insol vitreous materials consisting of a silicate, such as Na-Al silicate. In the case of AN, its particles are sprayed with a suspension of hydrated alumina in aq Na silicate during agitation at a temp of 105-130°. Agitation is continued until the temp has dropped to ca 60°. As this process is conducted at elevated temp, the insol hydrated alumina reacts with sol Na silicate to form an insol Na-Al silicate coating. This coating, however, does not prevent the leaching of AN if the grains are placed in contact with moist materials, such as the earth. This property is desirable if AN is intended for use as a fertilizer) 9)H.Brunel,FrP 58307(1953) & CA **52**,18961(1958)(Al alginate as a coating agent) 10)A.M.Dubrovitskii et al,ZhPriklKhim **27**,349-54(1954) & CA **49**,15185(1955) (Engl translation)(Dendritic structure of AN and its effect on caking) 11)Y.Ishikawa,JapanP 7593('54) & CA **50**,5950(1956) [Caking of hygroscopic materials can be prevented by treating their particles with a satd soln of AN contg a small quantity of carboxymethylcellulose or other substances, such as carboxyethylstarch or one of the organic acids(arginic, polyacrylic, polyuronic, thymus-nucleic or arabic] 12)H.Seifert,Chem-Ing-Tech **27**,135-42(1955) & CA **49**,7152(1955)(Discussion of the problem of crystal shape and its effect on caking and other props) 13)A.L.Shneerson et al,ZhPriklKhim **29**,743-7(1956)(Engl translation) & CA **51**,6063(1957)(Caking characteristics of AN) 14)NV Koninklijke Nederlandsche Zouitindustrie,DutchP 83128(1956) & CA **52**,7633 (1958)(Caking of NaCl is reduced by coating its particles with an aq soln of a Cd salt such as Cd chloride) 15)Ibid,DutchP 83383(1956) & CA **52**, 14110(1958)(Caking tendency of K sulfate, Amm sulfate or their mixts can be decreased by incorporating small quantities of an alkali dithionate) 16)G.Oyama et al,JapanP 9973('56) & CA **52**, 15853(1958)(Caking of hygroscopic N compds such as AN can be prevented by incorporating some Na silicate) 17)J.B.Rust & L.Spialter,USP 2788280 (1957) & CA **51**,10974(1957)(Caking of inorg & org granular hygroscopic materials can be prevented by surface treatment with a Si halohydride or an organosilicon halide in which the org radical is aliphatic or aromatic) 18)A.P.Milovanov et al, RusP 105991(1957) & CA **51**,15056(1957)(Caking of AN in storage is prevented by adding to a soln of AN an extract obtained in the decompn of phosphorite with $HNO_3$. The soln is then neutralized with ammonia, vaporized, crystd and dried. As result of this treatment, the AN will contain 0.5-2.5% $P_2O_5$) 19)M.Iwase,JapanP 6616('57) & CA **52**,19289(1958)(An addn of one or more of the condensation products of an aliphatic amine and a fatty acid or resin acid prevents the caking of urea, AN, NaCl & of other compds) 20)J.Ames, BritP 805112(1958) & CA **53**,8557-8(1959)(Normal aliphatic primary amines with at least 12 C atoms or their salts as anticaking agents for AN) 21) M.Hoshikawa et al,JapanP 2866('58) & CA **53**, 12530(1959)(Ethylenediaminetetracetic acid as an anticaking agent for urea, AN, Amm sulfate, etc) 22)P.K.Kovtun et al,RusP 109465(1958) & CA **53**, 19323(1959)(A neutral noncaking product is obtained by treating AN with a small quantity of a metal hydroxide and carboxylic acids or their mixt with unoxidized or partly oxidized paraffinic hydrocarbons) 23)S.Varma et al,JSciIndResearch(India), **18B**,118-22(1959) & CA **53**,20660(1959)(Gypsum as an anticaking agent for AN) 24)P.O.Marti,Jr, USP 2901317(1959) & CA **53**,22956(1959)(Caking of AN particles is prevented by coating them with comminuted CuO or $Cu_2O$) 25)R.R.Irani et al, IEC **51**,1285-8(1959) & CA **54**,4072(1960)(Study of effectiveness of several common conditioners on improving flow props and inhibiting caking) 26)

R.R.Burns,USP 2920937(1960) & CA **54**,7958 (1960)(Caking of inorg salts such as AN, Amm sulfate or borax is prevented by the addn of a small quantity of 1,2- subsituted imidazolinium salts)

**Calcinit**(Calcinite). A Ger mining expl which existed in several modifications. See PATR **2510** (PB 161270)(1958),p Ger 23

**Calcium**, Ca, at wt 40.08; silvery- wh, soft metal which must be kept in tightly stoppered bottles; d 1, 578 at 15°; mp 810°; sublimes below its mp; sol in acids; decomposes water liberating hydrogen gas. Can be prepd by electrolyzing molten Ca chloride(Refs 1,2,3 & 5). Its toxicity is discussed in Ref 4. Some of its salts were proposed for use in smoke producing compns (Ref 6)
*Ref:* 1)Mellor **3**(1923),626,631 & 637 2)Kirk & Othmer **2**(1948),744- 5 3)Gmelin,Syst Nr **28**(1950-1957) 4)Sax(1957,423-4 5)CondChemDict(1961), 198 6)J.DeMent,USP 2995526(1961)

**Calcium Acetate.** See Vol 1,p A28- L

**Calcium Acetylides.** See Vol 1,p A71

**Calcium Bromate.** See under Bromates

**Calcium Carbides.** See Vol 1,pp A71- R & A72- L

**Calcium Carbonate.** See under Carbonates

**Calcium Chlorate.** See under Chlorates

**Calcium Chloride.** See under Chlorides

**Calcium Cyanamide.** See under Cyanamides

**Calcium Fluoride.** See under Fluorides

**Calcium Hydride.** See under Hydrides

**Calcium Hydroxide.** See under Hydroxides

**Calcium Hypochlorite.** See under Hypochlorites

**Calcium Hypophosphite.** See under Hypophosphite

**Calcium Nitrate.** See under Nitrates

**Calcium Nitride.** See under Nitrides

**Calcium Nitrite.** See under Nitrites

**Calcium Oxide.** See under Oxides

**Calcium Perchlorate.** See under Perchlorates

**Calcium Permanganate.** See under Permanganates

**Calcium Peroxide.** See under Peroxides

**Calcium Phosphide.** See under Phosphides

**Calcium Picrate.** See under Picrates

**Calcium Plumbate.** See under Plumbates

**Calcium Resinate.** See under Resinates

**Calcium Silicate.** See under Silicates

**Calcium Stearate.** See under Stearates

**Calcium Sulfate.** See under Sulfates

**Caliber** is the diameter of the bore measured between opposite lands of a rifled small arm or an artillery weapon. The *lands* of a weapon are the raised portions of the rifling in a bore, and the spaces betw the lands are called grooves

The diameter of small arms(which in the US includes all weapons whose bore is .60 inch or less) is expressed in the US in hundredths of an inch, in Gt Britain in thousandths of an inch and in all other countries in millimeters. The word caliber(or the abbr Cal) is placed before the number, such as Caliber .30(or Cal .30). The diameter of a bullet(see BULLETS) is always a few thousandths of an inch greater than the caliber designated

The calibers of current US small arms are listed in Vol 1,p A386- L

For some firearms, such as *shotguns*, it is customary to express the interior diameter as *gage*, which is the number of spherical lead bullets, of the diameter of the gun bore, required to weigh one pound. Thus, the bore measurements or shotguns of popular sizes, stardardized on above basis, are as follows (Ref 5):

| Size of Gun Gage | Diam Inch | Size of Gun Gage | Diam Inch |
|---|---|---|---|
| 8 | 0.835 | 14 | 0.693 |
| 10 | 0.775 | 16 | 0.662 |
| 12 | 0.729 | 20 | 0.615 |

For artillery weapons, the caliber is expressed in the US & GtBrit in inches(and sometimes in millimeters), while in other countries in millimeters or centimeters. The word Caliber(or the abbr Cal) precedes the number, such as Cal 3-inch Field Gun. When the word "calibers" follows the number, such as in the definition: "Gun,16-inch, 50 calibers", it means the length of the barrel is equal to 50 times the caliber(in this case 16") which gives 50 x 16= 800 inches

Calibers of current US artillery weapons are listed in Vol 1,p A386-R. Calibers of WWII German weapons are listed in Ref 4

*Refs:* 1)Anon, "Ammunition Inspection Guide", TM **9-1904**(1944), 7 2)Ohart(1946), 10 & 64-5 3)G.M.Barnes, "Weapons of World War II", Van Nostrand, NY(1947) 4)PATR **2510**(PB No 161270)(1958),pp Ger 227-59 5)Glossary of Ord (1959), 130 (See also Refs in Vol 1,pp A387-L to A391-L)

**Calibration of Chemical Glassware at Plants Manufacturing Explosives and Related Items.** Inasmuch as practically none of the commercial volumetric glassware (such as flasks, burettes, pipettes, picnometers, nitrometer measuring tubes, etc) is precisely calibrated by the manufacturer, it is advisable to recalibrate it in the laboratory where glassware is to be used. It is important to remember that none of the volumetric glassware should ever be heated to high temps (above ca 50°). This is because glass, expanded by heating, does not resume its original form for some time after heating

A complete description of methods used during WWII at the Keystone Ordnance Works, Meadville,Pa was given in Ref

*Ref:* G.D.Cliff & B.T.Fedoroff, "A Manual of Explosives Laboratories", Lefax,Philadelphia, Vol 3, Chapter 2(1944),pp 19,21,23,24 & 28

**Calibration of Hydrometers.** A simple, rapid method is described in Ref

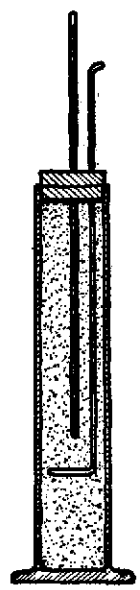
*Ref:* Cliff & Fedoroff, Vol 3, Chapter 2(1944),p 35

**Calibration of Laboratory Thermometers.** A simple, rapid method is described in Ref

*Ref:* Clift & Fedoroff, Vol 3, Chapter 2(1944), p 33

**Calibration of TNT Thermometers.** Thermometers used for detg "setting points" (solidification points) of TNT by method prescribed by US Govt (See Specification JAN-T-248) are calibrated for total immersion at the USBurStds. As the Govt method of detg setting point is tedious and time consuming it is seldom used in plant control labs, except when lab results do no check with those obtd by Govt Inspectors. Just as precise and much quicker are the "evaporting dish" and "custard cup" methods, both of which employ thermometers calibrated to partial immersion when using such thermometers, it is essential that the lab temp stays within about 10°

Following is the procedure for calibration of thermometers intended to be used as "standards" for plant control detns of sp's of TNT's: a) Obtain a 50-lb box of good grade TNT b)Spread the contents on a very large piece of strong paper and mix thoroughly with a large spatula and also by lifting and lowering alternately the four corners of the paper c)Bottle and keep in 1 or 2 l wide mouth bottles, corked and sealed with paraffin. Keep away from light

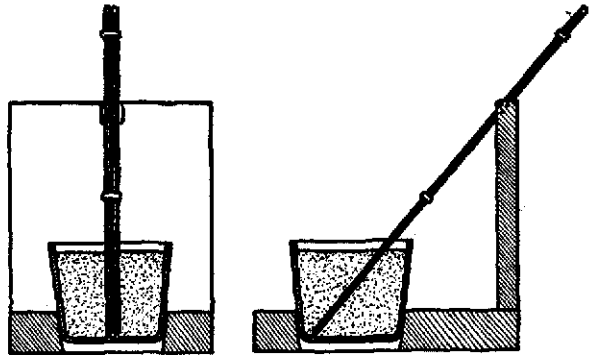


d)Place in a large casserole about 1kg of the TNT sample and heat it in a steam oven. After melting, heat the material ca 10 mins to dry it e)Arrange an apparatus as represented in Fig. The cylinder should be of Pyrex, 2-2½" in diam and ca 20" long f)Heat the cylinder by placing it in the oven g)Fill the cylinder to the top with molten TNT and insulate the apparatus by placing it in sawdust, cotton, etc h) Measure the temp of TNT with an ordinary thermometer and if it is betw 82-83°, insert a stopper fitted with a stirring loop and a BurStds thermometer, with .02 divisions and calibrated to total immersion i)Arrange the thermometer so that the top part of the stopper is on the level with the 80.20° mark j)Stir constantly by moving the rod up and down k)Watch the thermometer and as soon as the temp, after falling steadily, starts to

rise, stop stirring l)Note the temperature every 15 seconds (by using special reading glass)until the maximum is reached and record this temp as sp. Add or subtract the bore corrections as shown on the BurStds Certificate attached to the calibrated thermometer. As the cylinder was filled to the top, the thermometer was immersed in TNT to ca 79.7°, leaving 0.5° of scale under the stopper. We may assume, without introducing an error of not more than 0.01°, that the thermometer was totally immersed

Suppose now that correction of BurStds thermometer is +.05° and its reading for sp of TNT is 80.20°. This means that sp of TNT is 80.20+.05= 80.25°. Save the rest of this TNT (few pounds) and use in future as the *standard TNT*

The BurStds thermometer and other thermometers calibrated for total immersion should be used only for detn of sp of TNT by the Specification Method, while for routine tests the thermometers calibrated to partial immersion should be used. For calibration of such thermometers proceed as follows: a)Make a mark ca 5cm from the bottom of the bulb and at least 1cm above the upper (small) mercury bulb on each special thermometer graduated in 0.1 or 0.05° b)Tie thermometers together in pairs (with a strip of rubber tubing) and be ready for calibration by custard cup method c)Wash and dry a Pyrex custard cup ca 2.5" in diam and ca 2.5" deep. In order to hold the cup and thermometers in place, use a wooden stand as shown in Fig



d)Fill one or several 180-ml electrolytic beakers to the top with "standard TNT" and melt the TNT on a steam bath. Add more TNT and continue heating until the temp is betn 85 & 87°

*Note:* If it is suspected that TNT is slightly moist, continue heating and stirring for addnl 10 mins. If TNT is very moist, add 1-2 tablespoonsful of anhydrous Ca chloride and continue heating and stirring the liq TNT becomes clear e)Heat one or several custard cups to ca 85° and place them on wooden stands f)By means of a pair of tongs, remove the beaker from the steam bath, wipe adhering water from the outside (especially around the edges) and pour the TNT into the custard cup g)Insert a stirring rod about 6" long, stir for few seconds and then leave without stirring until a very light crust starts to form on the surface of TNT. This will mean that temp of the molten mass has dropped to about 2-3° above sp

*Note:* If thermometer is introduced in the mass while temp is much higher than sp of TNT, serious errors may be introduced, because the expanded glass does not immediately resume its original volume. Also broken mercury columns are more likely to occur

h)Break the crust by means of the stirring rod and insert two TNT thermometers as shown in Fig i)Stir the mass with the glass rod (and not with the thermometer to avoid breaking of Hg bulb). Lift the thermometers and carefully remove the crust of TNT using a spatula or knife. Reinsert the thermometers and lean them against the notch of the stand. Be sure that TNT covers the immersion mark of thermometers (See opn a) j)Stir occasionally watching the thermometers with the naked eye k)The temp will drop until it reaches ca 1° above the sp. After this the temp will start to rise due to the latent heat of crystn. At this point the mass turns fudgy and becomes slightly lighter in color l)Stop stirring and slightly raise the thermometers so that the bottoms of lower bulbs are ca 1mm above the crust on the bottom of the cup, while the upper (small) bulbs remain completely covered by TNT m)While holding thermometers steady in this position, observe closely the temp (which should rise slowly at this point of detn) using a special magnifying reader. As soon as the temp stops rising and remains stationary for some time, take a reading and record it as the sp

*Note:* If a reading lens is used, hold it flush against the stem of the thermometer and read the temp to 0.01°

*Calculation:* Let us suppose the thermometer No 1 shows 80.31° while No 2 shows 80.21°. As the true sp of "standard TNT", as detd by the BurStds thermometer was 80.25°, it means that the total correction for No 1 will be minus .06°, while for No 2, plus .04°

*Cleaning of Glassware Used in Calibration of TNT Thermometers.* As soon as the reading is taken, remove the thermometers from the cup and hold

one of them with the left hand close to the adhering mass of TNT, with index finger underneath the mass. Using the right hand and a piece of paper, push the TNT off the bulb. If TNT became too hard, remove it by means of a spatula of knife. Another method is to place the bulb of thermometer for ca 10 mins in a jar contg nitration grade toluene. The same toluene may be used for many cleanings and then returned to the plant for use in the nitration to TNT. This method is safe and recommended especially if the crust is allowed to cool so that it becomes very hard. A hot thermometer should never be inverted or placed horizontally, in order to avoid splitting of the mercury column. For removing TNT from custard cups allow the contents to cool to RT and then tap the cups lightly in an inverted position against a wooden object (such as a table), but not against metal or stone. The TNT will be released as a solid piece

*Ref:* Clift & Fedoroff, Vol 3, Chapter 5(1944), pp 4–6

**Calibration of Weights and Analytical Balances.** A simple, rapid method is described in:

*Ref:* Clift & Fedoroff, Vol 3, Chapter 2(1944), pp 36–8

**Caliche or Nitre-Bed.** A term used in Chile for a layer of gravel or rocks contg Na nitrate (Chile saltpeter) together with Na sulfate (salt cake), Na chloride (table salt) & small amts of other salts. Caliche varies in depth from 2 to 20ft and is covered by 1 to 12ft of sand overburden. The deposits are found in a desert in Atacama of province Tarapaca (Northern Chile) extending 400 miles north and south with a width of 5 to 40 miles. Deposits of Na nitrate, on a smaller scale have been found in Argentina, Bolivia, California and Peru (Ref 1, 2 & 3)

The modern process for extraction of Na nitrate from caliche (as well as from lower grade ore called *costra*) was developed by Guggenheim Bros of New York. Essentially it consists of the following operations: a)The sandy overburden is removed by means of large drag lines b)The caliche is broken by blasting, loaded by steam shovels, and transported to the leaching plant by means of a temporary electric RR) c)The caliche is crushed into small pieces and then leached in large open vats counter-currently with water at ca 40° d)The nitrate is recovered by crystn at 5°, and separated in centrifuges from other salts which have remained in soln e)Before sacking, the product thus obtained is melted and sprayed to form little globules in order to prevent caking during shipment

More detailed info on production of Na nitrate may be found in Ref 1 & 2

*Ref:* 1)Wm.H.Rinkenbach,ArOrd **11**, 110–14(1930) 2)H.L.Reichart & H.W.Schulz,ChemMetEngrg **46**, 464–6(1939) 3)Kirk & Othmer **12**(1954), 605

**Caliver or Arquebus of Caliber.** See under Arquebus in Vol 1,p A488-L and under BULLETS, Historical

**Callenburg's Dynamite,** patented in 1899, consisted of NG 30, collodion cotton 1, K nitrate 40, $MgSO_4.7H_2O$ 24, turpentine 4 & Na carbonate 1%. It was practically nonhygroscopic and only slightly sensitive to shock or heat

*Ref:* Daniel(1902), 105

**Cal-Nitro.** A trade name for AN compn manufd by Semmett Solvay Co of Hopewell,Virginia for use as a fertilizer. It is less reactive with paper and sawdust than FGAN(see Vol 1,p A364), does not yield significant amts of expl gases (when decomposed at relatively low temps) and the bagged material is slightly less fire hazardous than bagged FGAN(see also Uraform-AN)

*Ref:* K.G.Ottoson, PATR **1682**(1948)

**Calomel.** See Mercurous Chloride under Chlorides

**Calorie or Calory.** In metric system it is the heat required to raise the temp of 1g of water from t° (such as 15,18 or 20°) to (t+1)°. This is called "small" or "gram-calorie" (abbr cal). There is also "large" or "kilogram-calorie" (abr Cal or kcal) which is equal to 1000cals. In English system, the so-called BTU or btu (British Thermal Unit), is the heat required to raise the temp of 1lb of w from 39.1 to 40.1°F. One BTU is equal to 0.252kcal

*Refs:* 1)H.S.Taylor & S.Glasstone, "A Treatise on Physical Chemistry", Van Nostrand, NY(1942), 439–40 2)Hackh's (1944), 160 3)Handbooks of Lange or of Chemical Rubber Co

**Calorific Constant of Explosives or Propellants.** It is defined by Taylor et al, as the heat evolved or absorbed on decompn of 0.01g of a substance at const vol and at 33° (water liquid). It can be

calcd from the formula:

$h=q_H/(100 \times$ gram-molecular wt), where h is calorific constant and $q_H$ - *molecular calorific* value (see under Calorific Value of Nitrocelluloses and Propellants)
*Ref:* J.Taylor et al, JPhCollChem **51**, 584(1947), & CA **41**, 3967(1947)

**Calorific Values of Explosives.** Calorific value is defined by Weissberger (Ref 3) as "the heat evolved when the substance is exploded in the absence of oxygen except for what it contains itself". This quantity is practically the same as the heat evolved when the substance is exploded under normal operating conditions (such as in bore holes or in shells). Experimental techniques differ somewhat from those employed in ordinary combustion calorimetry. The bombs employed in calorific value techniques are smaller in capacity and possess very thick walls to withstand high pressures. For example the bomb described in Ref 2 is of 124cc capacity. It was developed at Woolwich Arsenal and modified by Taylor et al. The Parr Instrument Co of Moline, Illinois also manufactures similar thick-walled bombs

Calorific value of an explosive is closely related to the value called *heat of explosion* or *heat of detonation*, and if an explosive contains sufficient oxygen for complete combustion to $CO_2$ & $H_2O$, the calorific value may be considered as identical with the *heat of combustion*

For example, for NG which has oxygen balance to $CO_2$ & $H_2O$ equal to +3.5%, the above values are equal to 1615cal/g (or 341.1 kcal/mole) at const vol, at 20° & with water liquid (Ref 1)
*Refs:* 1) J.Taylor et al, JPhCollChem **51**, 580-92 (1947) & CA **41**, 3967(1947) 2) J.Taylor & C.R.L.Hall, JPhCollChem **51**, 593-8(1947) 3) A.Weissberger, Edit, "Physical Methods of Organic Chemistry", Interscience, NY, Vol 1, Part 1, p 591: J.M.Sturtevant, "Calorific Values of Explosives"

**Calorific Values, Calorimetric Values and Calorimetric Potentials of Nitrocelluloses and Propellants.** Taylor et al (Ref 2, p 580), define the *calorific value* as the heat evolved (in calories per gram) when a substance is exploded in a special calorimetric bomb capable of withstanding high pressure

The following experimental calorific values for NC's of various N contents, at const vol and corrected to 0° are reported by Taylor & Hall (Ref 2a, pp 606 & 609, tables 4 & 10):

| % N in NC | 13.24 | 13.10 | 12.73 | 12.16 |
|---|---|---|---|---|
| Calorific Values (cal/g) | 1063 | 1054 | 982 | 902 |

*Note:* Values for NC's are corrected for methane formation. If no correction for methane is made and the temp is that of experiment, the corresponding values would be: 1060, 1051, 980.5 & 900.5cal/g

Calorific values of proplnts can also be detd experimentally. They may be calcd also by using the following equation:

$Q=(aQ_A+bQ_B+....mQ_M)/(a+b+....m)$, where a=parts of component A & $Q_A$ its calorific value; b=parts of component B & $Q_B$ its calorific value, etc. The components may be either expl or nonexpl

If the compn of a proplnt is $C_pH_qN_yO_s$ and if F its heat of formation, then we might write

$$C_pH_qN_rO_s=pCO_2+(s-2p)H_2O+(q/2-s+2p)H_2+r/2N_2-40987p+67509s-F \text{ (Ref 1, p 585)}$$

The *molecular calorific value* of the above proplnt, at const vol, at 33° and with w liq would be;

$$q_H=-40657p+67343s-F,$$

where p=number of carbon atoms in proplnt, s=number of oxygen atoms and F=molecular heat of formation of proplnt
*Note:* The value $q_H$ may be either positive or negative accdg to whether heat is evolved or absorbed on the decompn and reaction of the compd

If the molecular calorific value is known, the corresponding calorific constant can be calcd using the equation given under Calorific Constant (Ref 2, pp 580-6)
*Calorimetric Value* is defined by Corner (Ref 3) as the value which is obtained by measuring the heat evolved when a propellant is burned in a bomb calorimeter contg an insert atmosphere. The temps are near 300° K. This value can also be calcd as shown in Ref 3, pp 127-8
*Calorimetric Potential, Apparant* (Potentiel calorimétrique, apparent in Fr). Tavernier (Ref 4, p 234) defines it as the quantity of heat evolved on the decompn of a proplnt, provided it does not do any exterior work (which means under const vol) and if the gases evolved in reaction are cooled (which means that the water is liquid). This value is, accdg to Tavernier, identical with the English value called "Calorific Value". A similar value was called by DePauw (Ref 1) "die Characteristik einer Substanz"

The above value may be called "potentiel

calorimétrique apparent normal" to distinquish it from "coefficient calorimétrique fictif" designated by Tavernier as $Q_a$(Ref 4,p 251). $Q_a$ is the heat liberated at const vol with w liq in cal/g. It is applicable to an org compd $C_xH_yN_uO_z$ with less oxygen than is required for complete formation of $CO_2$ & $H_2O$, but greater than that required to oxidize all carbon to CO. Equations are derived and discussed graphically to show that $Q_a=67409z-40698x-Q_f$, where $Q_f$ is the heat of formation of the substance and $12x + y + 14u + 16z=1$ from the formula $C_xH_yN_uO_z$. The values $Q_a$ are shown to be additive for a mixt in terms of the percentages of each, providing the O balance is within the same range

In Ref 6, Tavernier gives simplified equations for the explosion temperature at const vol, the calorimetric potential, the av sp heat at const vol, the force and the coeff of isentropic expansion for proplnts, $C_xH_yN_uO_z$, where $12x + y + 14u + 16z=1$ and $2x + y/2-z>0$ and $z-x>0$

Muraour et al(Ref 5,p 273) define "potentiel apparent" as the heat of explosion or deflagration, as detd in a calorimetric bomb at const vol either, in vacuum or in inert atmosphere. This differs from "chaleur de combustion" (heat of combustion) which is detd in the bomb in the presence of an excess of compressed oxygen. In the opinion of Muraour et al, it is much simpler, less time consuming, and more precise to det and use the values of heat of combustion in lieu of calorimetric values

Lamouroux (Ref 7) discusses conditions for detn of "potential calorimétrique apparent" of smokeless proplnts

*Refs:* 1)P.dePauw, SS **32**, 11(1937) 2)J.Taylor et al, JPhCollChem **51**, 580-92(1947) & CA **41**, 3967(1947) 2a)J.Taylor & C.R.L.Hall, JPhCollChem **51**, 593-8 & 606-11(1947); CA **41**, 4030(1947) 3)Corner, Ballistics(1950) 127-9 4)P.Tavernier, MP **35**, 233-58(1953) & CA **49**, 12832-3(1955) 5)H.Muraour, MP **35**, 273-86 (1955) 6)P.Tavernier, MP **37**, 225-68(1955) & CA **51**, 1609(1957) 7)M.Lamouroux, MP **40**, 241-5(1958)

**Calorimeter, Calorimetry & Calorimetric Determinations.** *Calorimeter* is any apparatus used for measuring the quantity of heat, absorbed or evolved, during any chemical or physical process. The art of measuring this heat is called *calorimetry* and the tests involved are known as *calorimetric determinations.* These tests include: determination of heats of combustion, formation, vaporization, fusion, solidification, sublimation, atomization, isomerization, solution, dilution, mixing, absorption, chemical combination and of chemical decomposition. The calorimeter may also be used for detn of specific heats and melting points (Refs 1-5,15, 20,22,24,25,26,27 & 28)

The most important of these tests is the determination of heats of combustion (See below)

The importance of calorimetry in the study of chemical reactions was recognized as early as ca 1790, when Lavoisier & Laplace invented the "ice calorimeter" (Ref 28)(See also Ref 3,p 21)

Further developments in calorimetry include the invention of the "twin-calorimeter" by Joule (1845) and its modification by Pfaundler (1869)(Ref 25,p 543); "phase-change calorimer" (isothermal) of Bunsen(Ref 15,p 796 & Ref 25,p 547); "labirinth flow calorimeter" (Ref 25,p 549); "adiabatic calorimeter" (nonisothermal), first used by Richards in 1905 (Ref 15,p 797) and modified by Yost, Osborne & others (Ref 25,p 550)(See also Ref 3,p 116)(Parr adiabatic calorimeter is described in Refs 16 & 29); "constant-temperature-enviroment calorimeter", first used by Nernst in 1907, was modified by Giauque in 1923(Ref 15,p 797)

Other calorimeters include: "heat-leak calorimeters", such as of Thomas & Parks (Ref 25,p 545), "automatic calorimeters" such as of Andrews, Berl & Stull (Ref 25,p 551); "vacum-walled calorimeter" (Ref 3,p 153); "aneriod (unstirred) calorimeters" (Ref 3,pp 23,160-7), "rotating bomb calorimeters", such as of Popov, Shirokikh and of Hubbard (Ref 25,p 594); liquid-phase calorimeter" of Kistiakowsky (Ref 25,p 636), "gas calorimeter of Cutler-Hammer (Ref 18a), "calorimeter for gaseous heat capacities of Waddington (Ref 15,p 802), "flow calorimeter of Junkers" (Ref 15,p 805),"flow calorimeter of Osborne et al" (Ref 25,p 565), "flow calorimeter of Pitzer" (Ref 25,p 566), "flow calorimeter of Bennewitz & Schulze (Ref 25,p 567) and "flame calorimeter of Rossini" (Ref 25,pp 600-2). An apparatus for detn of heats of vaporization is described in Ref 25,p 615 and an "adsorption calorimeter" in Ref 25,p 618

Microcalorimeters are described in Ref 13

and a semi-microcalorimeter in Addnl Ref C

Some original papers on calorimeters are listed under "Addnl Refs on Calorimetry", which follows Refs

For detn of *heats of combustion* of gaseous materials or of volatile liquids, special calorimeters are used. In the "gas calorimeter", such as Cutler-Hammer described in Ref 18a, a predetermined vol of gas is burned and the evolved heat is transferred to a material of known sp heat (such as air or water) and of known temp. In a "flow calorimeter", such as of Junkers, described in Ref 15,p 805, the gases evolved, on burning, heat the w flowing at const rate and the heat is detd from the wt of w and the temp rise. In a "flame calorimeter", such as of Rossini, described in Ref 25,pp 600-2, the gaseous or highly volatile materials are conducted thru a silcon tube into a reaction chamber where they burn in an excess of oxygen. The reaction vessel is immersed in a calorimeter contg w, and further procedure is the same as for detn of heats of combustion of solid materials (See also Ref 22)

For detn of combustion of solid and non-volatile liquid materials, the most convenient method is to use a "closed bomb calorimeter". The first closed bomb calorimeter using oxygen under pressure was developed in 1881 by Berthelot (Refs 1,15 & 16). It was improved by Mahler in 1892 and by Atwater in 1899. These bombs were made of steel with linings of Pt, Au, Ni or vitreous enamel. This construction was costly, and complete protection from corrosion was not always obtained by lining. These difficulties were overcome in 1912 when Prof S.W.Parr developed a bomb made of an alloy "Ilium", comparatively inert to acids formed as result of combustion. This type of bomb is now manufd by the Parr Instrument Co, Moline, Illinois and the alloy used for its body consists of (approx): Ni 29, Cr 20, Mo 2, Cu 3, Si 1 & Fe 45%. The alloy is fundamentally similar to the original "Ilium". The trade mark of the present type of alloy is "Type 20 alloy". Parr combustion bombs are described in Refs 16 & 29, and on pp 16-17 of Ref 16 are given cross section views of "plain jacket calorimeter, series 1300" (Fig 8) and of "adiabative calorimeter, series 1200" (Fig 9)

Parr calorimetric bombs and calorimeters are very much in use in the US. These bombs are cylindrical in shape and are provided with covers which can be securely closed against leakage. Detailed descriptions of experimental procedures using Parr oxygen bombs and Parr calorimeters are in Ref 16

The Parr Co also manuf "peroxide bombs". These bombs are small pressure vessels in which samples are subjected to the intense oxidizing action of Na peroxide at a temp high enough to completly burn almost all C compds. Powdered K perchlorate and other reagents can be used together with peroxide to assist and accelerate ignition and to carry the reaction to completion (See Parr Specification No 2000)

In France, they have been using calorimeters which are modifications of original Berthelot apparatus. One such, "Landrieu-Malsallez, is installed in College de France (Refs 6 & 8). This calorimeter and the bomb of "Burlot-Malsallez" were manufd before WWII by the Usines Chimiques Rhône-Poulenc. Another Fr calorimeter is that of the Commission des Substances Explosives. It is specially designed for testing expls (Ref 6). Stettbacher (Ref 7,p 84) mentions that one of the bombs designed by Bichel was using 100g sample

For detns of heats of explosion, bombs similar to above but with thicker walls and of smaller capacities are used. Several bombs designed for this purpose are used at Picatinny Arsenal. All of them are cylindrical in shape and were manufd by the Parr Co. A similar small capacity bomb but made of Vibrac steel was developed in England by Research Dept, Woolwich (now Armament Research Dept). It is described in Addnl Ref n,pp 593-8. Stettbacher (Ref 7,pp 83-4) describes the bomb of J.Peters, which was of 40ml capacity, and used 10g samples. It could withstand very high pressures (See also Calorific Values)

*Refs:* 1)M.Berthelot, "Thermochimie", Gauthier-Villars, Paris (1897) 2)Marshall **2**(1917), 440-4 3)W.P.White, "Modern Calorimeter", ChemCatalogCo, NY(1928)(ACS Monograph No 42) 4)W.Ostwald, R.Luther & C.Drucker, "Physikalische Messungen", AkadVerlagsgesellschaft, Leipzig (1931) 5)C.E.Munroe & J.E.Tiffany, "Physical Testing of Explosives", Bur Mines Bull **346**, USGPO, Washington, DC(1931), 99-104 6)Vennin, Burlot & Lécorché(1932), 63 7)Stettbacher(1933), 78-85 8)Pepin Lehalleur (1935), 44 9) R.R.Wenner, "Thermochemical Calculations", McGraw-Hill, NY(1941) 10)Meyer(1943), 371-3 11)Vivas, Feigenspan & Ladreda **4**(1944), 82-4 & 95-104 12)B.F.Dodge, "Chemical Engineering Thermodynamics", McGraw-Hill(1944) 13) W.Swietoslawski, "Microcalorimetry", Reinhold, NY(1946) 14)S.Glasstone, "Textbook of Physical Chemistry", VanNostrand NY(1947), 207-11 15)

Kirk & Othmer **2**(1948), 793-808 (Calorimetry)(69 refs) and **13**(1954), 941-52 (Thermochemistry)(4 refs) 16)Parr Manual No **120**, Parr Instrument Co, Moline, Ill(1948) 17)F.D.Rossini, "Chemical Thermodynamics", Wiley(1950) 18)R.L.Weber, "Heat and Temperature Measurement", Prentice-Hall, NY(1950) 18a)Perry(1950), 1301-2 19) S.Valentiner, "Physikalische Grundlagen der Messtechnik in der Wärmewirtschaft", Verlag für angew Wissenschaft, Wiesbaden(1953) 20) J.Reilly & N.W.Ray, "Physico-Chemical Methods", VanNostrand, NY, vol 1 (1954), 495-527(Thermal measurements) 21)W.Moore, "Physical Chemistry", Prentice-Hall, NY(1955) 39-45 22)F.D.Rossini, Edit, "Experimental Thermochemistry, Interscience, NY(1956) 23) W.Roth & F.Becker, "Kalorimetrische Methoden für Bestimmung chemischer Reaktionswärmen", Vieweg, Braunschweig (1956) 24)Funk & Wagnalls, "New Standard Dictionary", NY(1958), 379-80 25)A.Weissberger, Edit, "Physical Methods of Organic Chemistry", Interscience, NY, vol 1,part 1(1959), 523-654: J.M.Sturtevant, "Calorimetry"; 26)R.S.Jessup, "Precise Measurements of Heats of Combustion with a Bomb Calorimeter", USNBS Monograph **No 7**, Washington, DC(1960) 27)S.Glasstone & D.Lewis "Elements of Physical Chemistry", VanNostrand, NY(1960) 28)Merriam-Websters (1961), 320 29)Parr Specifications No 1100-1105 (Describes various bombs and calorimeter and gives literature on Parr apparatuses; may be obtained on request from Parr Instrument Co, Moline, Illinois)

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**Calorite.** A French incendiary pyrotechnic device used during WWI. It was prepd in a form of a block by binding a mixt of powdered Al & Fe oxide with liq Na silicate. The dried material was ignited by means of a fuse combined with a primer consisting of powdered Mg & Ba peroxide

*Ref:* Pepin Lehalleur(1935), 475

**Cambrites.** Brit mining expls manufd by the Nobel's Explosives Co, Ltd, Ardeer, Scotland and placed in 1901 on the "Permitted List". The original *Cambrite No 1*, was prepd by mixing Nobel's Carbonite 92 & Amm oxalate 8%(Ref 1). This corresponded to compn given in Ref 2 as: NG 23, K nitrate 27, Ba nitrate 3.5, woodmeal 38, Amm oxalate 8 & Ca carbonate 0.5%. The compn of *Cambrite No 2*, was: NG 22-4, K nitrate 26-9, Ba nitrate 3-4.5, woodmeal 32-5, KCl 7-9 & Ca carbonate 1% (Refs 3 & 4). The compn No 2 is called in Ref 4 "smokeless powder"
*Ref:* 1)Daniel(1902) 105 2)Marshall 1(1917), 376 3)Thorpe 4(1940), 553-4 4)CondChemDict(1942), 288(not found in later editions)

**CAMERAS, HIGH-SPEED PHOTOGRAPHIC**(Used in Study of Rapid Events). In ballistic and aerodynamic investigations as well as in the study of explosive parameters, events are of such short duration that it is impossible to observe them visually. If such events are recorded photographically, detailed analyses and measurements can be made. Rapid events, such as detonotion, explosion, deflagration, blast effect, shock wave travel, flight of a projectile, etc are of such short duration, that special cameras have been designed and built to conduct these studies

High-speed photography (Momentphotographie or Kurzzeitphotographie in Ger and Photographie ultra-rapide in Fr) may be subdivided into "still" and "motion picture"

Accdg to EncyclBritannica (Ref 21,v 17,p 811), high-speed photography may be divided into: a)Single-instantaneous photography (which includes shadow or silhouette method,schlieren method, Kerr-cell method, reflected and stroboscopic light method, spark method & electronic flash method) and b)Motion-picture photography (which includes Bell Laboratories and other recently developed cameras)

High-speed photographs may be taken with oridnary reflected light, with monochromatic light, with infrared light, with ultraviolet light or with X-rays

*Historical.* The first attempt to photograph a rapid event was made ca 1850 by H.F.Talbot of England. He used a still camera and as a source of light the sparks generated by the discharge of a Leyden jar thru an air gap. Talbot's technique was applied in 1884-5 by E.Mach & P.Salcher to ballistic studies. Later L.Bull of Paris used an oscillation spark discharge to obtain a framing rate of 2000fps (frames per second). In 1909, C.Cranz designed an apparatus called "Ballistische Kinematograph", which was capable of taking up to 5000fps(Ref 1,p 351). An improved app taking up to 100000fps was devised in 1912 by C.Cranz & B.Glatzel(Ref 1,p 356)

The first successful moving picture camera and projecting apparatus were invented in 1895 by W.Lathan(US) and simultaneously by L. & A.Lumière(France). These and other early moving-picture cameras were hand-operated, using intermittent motion of the film and shutter. When they were modified to be electrically operated, their fastest picture taking rate became 128fps. As these cameras were much too slow for ballistic study, they were mechanically modified to obtain framing rates up to 10000fps(Ref 18,pp 31-2)(See also Ref 21,v 17,p 811)

**Cameras, Modern.** At present there are methods by which the rate of 10000fps can be exceeded and this is known as "ultra high-speed photography". For example, B.O'Brian of the Univ of Rochester, NY designed a camera with the rate of 15000fps and in England research was conducted to design a camera of 50000fps(Ref 18,p 101)

In the methods where a series of photographs are taken in rapid succession, there are two fundamental physical parameters, which are of importance: the "picture repetition rate"(R) and the "time of exposure"(T) of each individual frame. R is expressed as "frames per second" (fps) and T is given in microseconds. In different cameras, R may have values ranging from 24 to well over $10^6$ fps with T varying from ca 0.1 to 2000 microsecs. Closely associated with the value of R, is the "maximum time" (T) for which an event can be studied due to practical limitation of the method

Following is a brief description of devices and techniques which have been used to study rapid events:

*A)Cathode-Ray Oscillograph Photography.* It is a graphic method of obtaining permanent records in the analysis of amplitudes and frequences of elec & mechanical phenomena(Ref 3, 13a, 17b, 23c & 25c). The US Ordn Lab has developed and built a high-speed oscillograph capable of recording six traces simultaneously on a 35mm film. With the help of this instrument it was possible to investigate the function of guns, recording the breaking time of the primer bridge wire, the instant of appearance of flame from the primer port holes, the beginning of recoil of the

gun, and pressure-time records at three positions along the shell case(Ref 15a)

*B)Cine Camera.* Same as Motion Picture Camera

*C)Continous Film Movement Camera.* It is a device permitting one to take a rapid succession of pictures of an event on a continuously moving film. With this camera it is possible to achieve repetition rate of 16000fps(Ref 32)(See also Ref 18,p 14 and compare with "Intermittent Film Movement Camera")

*D)Drum Camera.* In this camera a strip of film is wrapped either on the outside or on the inside of a narrow hollow drum. The device, in which the drum is rotating at very high speed past optical components, is called a "rotating drum camera with moving film" to distinguish it from a camera in which the film is stationary on a fixed drum and succession of images is formed on the film by reflections from a rotating mirror. This latter type is known as a "rotating(or spinning) mirror camera". Some drum cameras combine a rotating drum with rotating mirrors (Ref 18,pp 14 & 80 -104; Ref 25,pp 289-336). Another type of drum camera uses "rotating prism" (Ref 15a; Ref 25,pp 351-7; Ref 31,p 367)

*Notes:* 1)Because of considerable mechanical difficulties for rotating the drums at very high speeds, the principle of "frame division" has been used to increase repetition rates of pictures. This subject is discussed in detail by Chesterman (Ref 18,pp 80-5 2)When photographic recording methods are used with the film wrapped either on the outside or the inside of rotating drum, but no "discrete" images are formed, the method is defined as "chronographic". For more info on this subject, see Ref 18,pp 85-9

*E)Electric Flash Camera.* See under Flash Photography

*F)Electronic Flash Camera.* See under Flash Photography

*G)Flash Photography.* It is the method of photographing objects with the aid of illumination produced by a flash. The flash may be produced by nonelectric, electric or electronic sources. A "nonelectric" flash may be produced by various "flash" powders, such as of Mg(Ref 8a); by detonation of a small expl chge, such as of Pentolite (Ref 18,pp 54-5); by explosively shocked argon gas (Ref 32); or by other methods (Ref 31,pp 49-65). An "electric" flash may be produced by one of the numerous "photoflash bulbs" or by "flash discharge tubes" (gas-filled or stroboscopic)(Ref 18,pp 48-51)(See also Ref 3,pp 3-10; Ref 12a; Ref 14; Ref 18,p 148 and Ref 25,p 51). These cameras may be called "electric flash cameras". The flash produced by an "exploding wire" is also used as a light source (Ref 28). An electronic flash is produced by various electronic tubes and the cameras may be called "electronic flash cameras" (Ref 29,pp 161-79; Ref 31,pp 443-68 and Addnl Ref q)(See also Intermittent Light Source Camera and Spark Photography)

*H)Flash Radiography.* See X-Ray High-Speed Photography

*I)Framing Camera, High-Speed.* A camera producing a series of "distinct" pictures (frames) at "framing rates"(R) above 100000fps may be so called. There are "single-framing" and "multiple-framing" cameras. AEC-Bowen, Beckman-Whitley, Image-Converter, Image-Dissector and Multiple Kerr-Cell cameras are examples of framing cameras (Ref 25a,p 23 and Addnl Ref hh)

*J)Image Converter Camera.* It consists of an electronic tube having a photocathode at one end and fluorescent screen at the other end with associated tube components. The image is formed on the photocathode. The electrons given off are relayed and focused onto a fluorescent screen by electronic means. The visible image can then be photographed by conventional methods (Ref 25, p 116; Ref 25a,p 23 & Ref 32)

*K)Image Dissector Camera*, also called "Image Splitting" or "Image Sampling" Camera. The image dissection techniques consists of sampling a large number of line or point images by means of slits (Ref 14a), grids (Ref 17b & Ref 25,pp 96-101), lenticular plates (Refs 23a & 25b)(and the like(Ref 32)

*L)Interferometer Camera.* E.Mach and his son L.Mach were the first to apply interferometer techniques to study of ballistic problems (Ref 1, p 275). The camera devised by them was improved by Zehnder and became known as "Mach-Zehnder Interferometer" (Ref 2,p 173; Ref 18,p 141 and Addnl Ref dd). Bennett et al (Addnl Ref cc)gave the theory of interferometric analysis and described the procedure used at BRL(Ballistic Research Laboratories), Aberdeen, Md for analysis of airflow around projs in flight. The app of Tolansky is described in Ref 31

*M)Intermediate Rate Camera or Medium Repetion Rate Camera.* A camera with repetion rate (R) up to 100000fps, in which the time scale of the event on projection of the film is multiplied by a factor of approx 4000fps may be so called. Many of such cameras both for 35 or 16mm films have been developed (Ref 18,pp 18 & 23; Ref 25,pp 337-60 and Ref 32)

*N)Intermittent Film Movement Camera.* A camera in which it is possible to record a rapid succession of images by arresting the film movement at the instant when exposure is desired, may be so called. Shutter mechanisms allow individual picture-exposure times to be varied over a ratio ca 20:1 (Ref 18,p 13)

*O)Intermittent Light Source Camera.* For some research studies it is often necessary to have a considerable number of pictures of rapid motion and yet each picture must have a short exposure time. The requirement is not so much for high repetition rate as for a series of high quality images of the event during a reasonably long time lapse. For these purposes a "stroboscopic light source" is very suitable (Ref 18,p 52). An Intermittent light source camera employed at NOL (Naval Ordnance Laboratory), White Oak,Md for study of underwater explns is described in Ref 15b,p 104

*P)Kerr-Cell Camera.* The discovery of Kerr in 1875, that when a transparent isotropic substance (such as glass, water or nitrobenzene) is exposed to a strong electric field, it becomes doubly refractive, is utilized in construction of this camera. The phenomenon discovered by Kerr is known as "electron-optical Kerr effect" or simply as "Kerr-effect". This effect can be measured by means of a "Kerr-cell", also known as "electro-optical shutter". It consists of a transparent enclosure contg two plates attached at a slight angle to each other and immersed in nitrobenzene medium, which is isotropic under ordinary conditions. In operation, the cell is placed between crossed polarizer inclined at an angle to the electric field consisting of two electrodes. Upon pulsating the electrodes, the isotropic medium(nitrobenz) becomes anisotropic and the polarized light is rotated due to the difference in the velocity of the components paralled and normal to the field. The amt of rotation is proportional to the length of the path and to the applied field strength. The exposure time of a Kerr-cell depends on the duration of the pulse and can be as short as $10^{-9}$ sec. However, the light transmission thru such a cell is only 7 to 15% (Ref 14a; Ref18,pp 77-8 and Ref 32)

One of the first cameras applying Kerr-cell to study ballistic problems was designed by Deutsch (ca 1930). His app was modified in 1932 by Cranz, Kutterer & Schardin to become known as "Kerreffekt-Chronograph" (Ref 2,p 165). Kerr-cell camera proved to be useful for photographing highly self-luminous effects, such as detonations (Ref 18,p 78). Pugh et al (Ref 18a) described a Kerr-cell camera for photographing metal jets squirted from lined conical cavities of shaped HE chges. Previous attempts to photograph them by visual light were unsuccessful because the velocity of such jets is extremely high, while their luninocity is very low. As a source of light Pugh used an "exploding wire" (See also Ref 25,p 133; Ref 29,pp100-2; Ref 31,pp 127-40 & 453-4)

*Q)Oscillograph Camera.* It consists, essentially, of a delicate mirror galvanometer, a tuning fork vibrating at a known high frequency, and a photographic app for recording time & galvanometer deflection. Oscillograph cameras have been used in conjunction with a "solenoid chronograph" for precisely measuring velocities of projectiles as described in Ref 4,pp 90-1 (See also Ref 1,p 83; Ref 2,pp 163-5 and Ref 3)

*R)Photoelectric Cell Camera.* A camera using a photoelectric cell as a source of illumination. These cameras may be used to study the following ballistic problems: a)Detn of duration and intensity of a muzzle flash b)Time of burning of a fuse and c)Velocity of a projectile. In the study of problems (a) and (b), the light produced by the event impinges on a photoelectric cell thus causing an elec current to be produced. In the study of problem (c) the camera (such as used at Aberdeen Proving Ground), is so constructed that when the proj passes overhead, the reduction in light which impinges on the cell is recorded, by means of an amplifier, on an "oscillograph" or on another instrument. This method was found especially suitable for measuring velocities of large caliber projs because they are fired at angles of elevation too great for convenient use of "solenoid" or other types of chronographs (Ref 2, pp 168-71; Ref 9 and Addnl Refs a & b)

*S)Radiography of High-Speed Events.* See X-Ray High-Speed Photography

*T)Reflected Light Photography.* Any method in which a photograph is taken by reflected light (such as flash or spark photography) may be so called. The reflected light method requires, in general, more energy and longer exposure time than the "shadow" or "silhouette" method (Ref 21, v 17,p 811)

*U)Rotating Drum Camera.* See under Drum Camera

*V)Rotating Lens Ring Camera.* See Ref 31,pp 350-4

*W)Rotating Mirror Camera.* See under Drum Camera

*X)Rotating Prism Camera.* See under Drum Camera

*Y)Schlieren Method Camera.* "Schlieren" is the Ger word for "striae" or "streaks" which are

caused by regions of nonunifrom refraction in gases, liquids or solids. This phenomenon was first observed in 1859 by J.Foucault of France who designed a test, called a "knife-edge test", based on this phenomenon. The test was improved in 1864 by A.Töpler (Germany) who coined the name "Schlieren-Methode" (Ref 1,pp 258-63; Ref 2,p 175 and Ref 18,pp 109-18)

E.Mach of Austria (1887) and later (1892) his son L.Mach were the first to apply the "Schlieren-Method" to study ballistic problems. Since then the techniques have been improved and the method is used extensively wherever it is required to study photographically rapidly changing disturbances which cause refractive index changes in the air, or in other media in which disturbance takes place (Ref 31,pp 324,497 & 508). The combined "schlieren-interferometric method" is described in Ref 31,pp 525-9

*Z)Shadow (or Silhouette) Camera.* In this method invented ca 1880 by Dvorak, the shadow of a small object (such as a bullet), moving at a high velocity betw a pulsed short-duration point light source and a stationary photograpaphic plate (or film) is recorded on the plate (or film). The distance of the plate (or film) from the light source should be large in relation to its distance from the object in order to avoid diffraction effects. Alternatively, a condenser may be used betw the spark & the object

Accdg to C.Cranz [SS 9, 61(1914)], Boys of England was the first to apply the shadow method to study ballistic problems (1893) and later, the method was used by E.Mach (Ref 18,p 108)

A short description of shadowgraphy of bullets, utilizing sparks as the source of light is given in Ref 21,p 169

In addn to shadow photographs taken with visible light, there are shadowgraphs taken with X-Rays (See Ref 14b and under X-Ray High Speed Photography)

Shadow method may be combined with other methods, such as with "Schlieren-Method" (See also Ref 25,p 81; Ref 31,pp 209, 369, 508 & 530 and Addnl Refs c & bb)

*AA)Silhouette Photography.* See Shadow Photography

*BB)Smear Camera; Streak Camera and Sweeping Image Camera.* Accdg to definition given in Ref 31,p 322, a "Smear Camera" is an instrument which records continuously (as contrasted with intermittent recording of a "framing camera"), the changes of light intensity along a line as a function of time. In the "Streak Camera", such as developed by the US National Research Council (Ref 31,p 303), image of the object to be photographed is focused on the film plane. The image or film may be moved at a controlled rate so as to produce on the film the "streaked" photo, which can be used to calculate the velocity of the object under study. For example, a luminous cylindrical shock wave expanding from a point source would form a triangular image on a streak-camera film, the slope of the edge of the image being proportional to the velocity of the shock wave. Beard (Ref 15a,pp 99-101) gives description of the "Streak Detonating Camera", installed ca 1949 at NOL, White Oak,Md. "Sweeping Image Cameras" are discussed in Ref 25,p 289; Ref 30a and Ref 31,pp 309-17 & 319-21. The principal part of these cameras is the optical train which consists of a collimator lens (which renders the light from the image points into paralled beams), a rotating mirror (which sweepsthese beamsinto an arc) and a box camera (which is set at infinite focus to receive the reflected beams). The "sweeping light beams" form images which move across the film plane while, at the same time, remaining in sharp focus

*Notes:* a)Liddiard (Ref 31,p 328) states that, as far as he knows, the terms "smear", "streak" and "sweeping image" are used interchangeably. In NOL, White Oak,Md, they prefer to use the term "smear" to emphasize the fact that the photo contains a series of "smears" as against the "portrait" type of photo obtained with "framing" cameras b)Veagh (Ref 31,p 328) states that at ARDE, England, the term "graph-drawing machine" is used for "streak" or "smear" camera c) Chesterman (Ref 18,p 85), calls "portrait type" images "discrete" which would suggest the term "indiscrete" for "smear-type" images

*CC)Spark Cinematography.* See Stationary Film with Multiple Spark Camera

*DD)Spark Photography.* When it is required to have a source of light of brief duration (below 1 microsec) an elec spark in air (or in inert gas) is used. Sparks may be used in "Shadow", "Schlieren" and "Interferometric" techniques

The spark produced by a Leyden jar was the earliest light source used for the study of rapid events by photography (F.Talbot in 1851). This type of spark was first applied to ballistic investigations in 1884 by E.Mach & P.Salcher. In later cameras, a spark was produced by electronic or other devices, such as "guided spark flashlamp", etc (See Ref 1,pp 258-9 & 349-62;

Ref 2,pp 176-93; Ref 18,pp 17 & 105; Ref 21, vol 21,p 169; Ref 25,p 62; Ref 29,pp 102-7 and Ref 31,pp 11,13,17,41,369,489 & 498)(Compare with Flash Photography)

*EE)Speedlight or Speedlamp Photography.* It utilizes the light from the discharge of a charged electrical condenser or capacitor thru a tube (glass, Pyrex or quarz), provided with metallic end electrodes and filled with gas (such as argon) which has the property to fluoresce momentarily to a high brillance. Devices producing "speedlight" are known commercially as "Speedlamp", "Speedflash", "Electronic Flash", etc. A "Speedlamp" gives only one short flash every time the current is switched on, and should not be confused with "Stroboscope", which flashes repeatedly at short intervals (See Refs 7, 12 & 29)

*FF)Stationary Film with Multiple Spark Camera or Spark Cinematography.* It is employed for extremely rapid events (such as at R=240000fps or as high as $10^6$), when ciné techniques and drum cameras prove to be unapplicable to moving films at such high speeds. With this camera a limited number of discrete images are formed successively on a stationary film (or photographic plate) by means of a series of illuminating gaps discharged in very rapid succession (Ref 1,pp 349-62; Ref 2,pp 186-93 and Ref 18,p 15)

*GG)Streak Camera.* See Smear Camera, Streak Camera and Sweeping Image Camera

*HH)Stroboscopic Camera* (from the Greek word "strobo" meaning "intermittency"). In this camera is utilized a lamp (such as neon-filled "thyratron") which produces extremely short flashes of light repeated in rapid succession, the timing of which is instigated by the camera mechanism. The camera, itself, is shutterless and has merely the function of transporting the film continuously at a high rate thru the mechanism, and the extremely brief duration of the flash "arrests" the motion of the film during photography of the event. These cameras can be utilized to make either multi-exposures on one film (showing progression of some motion) or to slow down, or to stop an apparently repetitive motion. They also can be synchronized with motion picture cameras to produce "slow motion picture stroboscopic cameras"

Stroboscopic cameras have been extensively used for solving ballistic problems (See Ref 1,p 341; Ref 2,p 159; Refs 6,10,11,13,17,18,19,25, 26,29,31 and Addnl Ref 1)

*Note:* Accdg to Chesterman (Ref 18,p 33), "stroboscopic" is not, strictly speaking, a correct term for the camera so named, because "stroboscope" is an instrument for observing the successive phases of a periodic motion by means of a light periodically interrupted. The early "stroboscopes" used mechanical modulation of the light, but with the development of gas discharge, the successive flashes of the light have been achieved electrically. When these flashing light sources began to be used as photographic illuminants, they were often loosely termed "power stroboscopes"

*II)Sweeping Image Camera.* See under Smear Camera; Streak Camera and Sweeping Image Camera

*JJ)X-Ray High Speed Photography or Radiography of High Speed Events.* When an optical method cannot be applied (either due to the event being accompanied by an intense light flash sufficient to obliterate the effect under study), one usually resorts to "X-Ray Photography", also known as "Radiography". In this method, a burst of x-rays of great intensity and of over-all time duration of the order of 1 microsec or less, is utilized to produce shadow radiographs of objects which are either completely or partially optically opaque (such as bullets, metal fragments in detonation products, etc). One of the important applications of x-ray techniques is investigation of behavior of conical metallic linings during detonation of shaped charges. Here the light emitted by linings is rather weak in comparison with the flash produced on deton of HE chges and in photographs by optical methods (except Kerr-Cell techniques), only the latter flash is visible (Ref 18a and Addnl Ref g). Other applications of x-ray techniques to ballistic problems are discussed in Refs 14c, 18, 25, 25a, 31 and Addnl Ref f)(See also Ref 22)

*Note:* Cook (Ref 25a,p 23) gives a table listing high-speed cameras presently employed in detonation studies. Three types of cameras are listed: "streak", "single-frame" and "multiple-framing". Of these, Cook considers the "streak camera" as "a work horse" of the modern explosives laboratory, along with the "pin oscillograph" and the "rotating-mirror framing camera"

The section on "Cameras, High-Speed, Photographic" was reviewed by F.R.Schwartz of PicArsn, Dover, NJ

*Refs:* 1)Cranz vol 3(1927), 83, 257-67 & 384-408

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"High-Speed Photographic Facility for Study of Detonation", (Presented at the 14th Meeting of PicArsnScientificAdvisory Council, on April 26, 1957)(Confidential; not used as a source of info) *Addnl Refs:* a)E.M.Shinkle, ArOrdn **11**, 93-100 (1930)(High-speed photography for testing weapons) b)P.Bernard, MAF **12**, 425(1933)(Use of photo-cells in ballistics) c)W.Payman & D.W.Woodhead, MAF **12**, 741(1933) [High-speed photography (including "Schlieren" & "Shadow" methods) in ballistics] d)A.Magnan, "Cinématographie Ultra-Rapide", Hermann, Paris (1933) e)H.E.Edgerton, TransAmInstElecEngrs **54**, 149-53(1935)(High-speed motion pictures) f) C.M.Slack & L.F.Ehrke, JApplPhys **12**, 165-8 (1941)(X-ray high-speed photography) g)J.L.Boon, JSocMotPictEngrs **43**, 321-7(1944)(Eastman high-speed camera, Type III) h)M.P.Vanyukov, ZhTekhnFiz **16**, 889-92(1946) & CA **41**, 1106 (1947)(A device for photographing explns) i)W.W.McCormick et al, JApplPhys **19**,221-5(1948) (A microflash unit for ballistic photography) j) D.Croney, Nature **160**, 490-1(1948) & CA **43**, 3197(1949)(High-speed mirror camera for photographing the process of luminous detonation front inside transparent liquid expls) k)H.E.Edgerton, JSocMotPictEngrs **52**, 8-23(March 1949)(Elec flash photography) l)K.J.Germeshausen, Ibid, 24-34(March 1949) m)M.Beard, Ibid, 99-101 (Streak detonation camera) n)M.Beard, Ibid 105-6 (Rotation prism camera) o)J.C.Clark, JApplPhys **20**, 363-70(1949)(Flash radiography applied to ordnance problems) p)D.K.Weimer et al, Ibid 418 (Interferometric camera) q)W.T.Whelan et al, JSocMotPictEngrs **52**, 116-29(March 1949) (Electronic flash lighting) r)V.E.Bergdolt et al, PhysRev **76**, 879(1949)(Interferometric method in ballistics) s)F.D.Bennett & W.C.Carter, Ibid 880 (Interferometric method in ballistics) t)H.F.Quinn et al, JApplPhys **21**, 995-1001(1950)(Kerr-cell camera and flash illumination unit for ballistic photography) u)C.A.Adams, PrRoySoc **204A**, 19-20 (1950)(Optical streak cameras for observation of explns on the field-trial scale) v)G.K.Ashford et al, JChemPhys **18**, 1112-13(1950)(Detn of burning velocities from shadow and direct photographs of a flame) w)A.J.Zaehringer, Rocketscience **4**, 65-6 (1950)(Flame photography of BkPdr) x)J.S.Courtney-Pratt, ProRoySoc **204A**, 27-9(1950)(High-speed photography using as a light source detonation of LA) y)E.M.Pugh et al, JApplPhys **22**, 487-93 (1951)(Kerr-cell photography of rapid events) z) D.W.Woodhead & R.Wilson, Nature **167**, 565-6 (Rotating camera for investigation of "fading" of detonation in cones of expls) aa)I.T.Okawa, JIndExplsSoc, Japan **13**, 247-54(1952) & CA **49**, 5841(1955)(Study of muzzle-flash by high-speed photography) bb)P.Liebessart, Science et Industries Photographiques **23**, 14-16(1952) & CA **46**, 6533(1952)(Shadow photographic study of combustion of detonating cords) cc)Royal Photographic Society of Great Britian, "Photography in Science and Industry", London (1952) dd)F.D.Bennett et al, JApplPhys **23**, 453-69(1952)(Interferometric method) ee) G.D.Kahl & F.D.Bennett, Ibid, 763-7(Mach-Zehnder interferometer) ff)M.Lorant, Functional Photog **5**, 4-6(March 1954)(New photographic techniques in HE research) gg)M.Sultanoff & R.L.Jameson, JSocMotPictTelevEngrs **69**, 113-15(1960)(New observations of expl phenomena by submicrosecond color photography)

**Camouflet.** When a missile has penetrated so deep ly into the ground that no surface effect results from the expln, but instead a rough spherical cavity is formed be low ground level, the cavity is called camouflet. This term is also applied to the explosive that makes such cavity (See also under Blast Effect in Earth)

This is also applied to a military demolition chge used by the defenders to destroy the attackers' mine-galleries without breaking the surface of the earth. If the surface is broken the resulting crater might become a shelter for assaulting troops which is not desirable from the point of view of defenders (Ref 1)
*Refs:* 1)EncyclBritannica **4**(1952), 672 2)Anon, "Military Explosives", TM **9-1910**(1955), 77 3) C.Randall, "Camouflet Experiments in Ice", NavOrd Rept **4548**(1958)(Conf)(Not used as a source of info 5)Glossary of Ord(1959), 54 5) Merriam-Webster's(1961), 322

**2-Camphanone.** Same as Camphor

### Camphene and Derivatives

*Camphene* {called 2.2-Dimethyl-3-methylen -bicyclo-[1.2.2]-heptan in Beil}, $C_{10}H_{16}$, mw 136.23; col crysts, mp ca 50°. Other props & prepn in Beil **5**, 156, (82) & [105]. Used for manuf of synthetic camphor and as camphor substitute

**Nitrocamphenes,** $C_{10}H_{15}NO_2$; mw 181.23, N 7.73%. Three forms are described in the literature: a)*ω-Nitrocamphene,* called

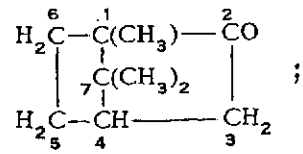
"Camphenilnitrit" by W.Jagelki [Ref 1,pp 161, (85) & Re 2] lt yel ndls(from ligroin), mp 66°; puffs off at higher temps; can be prepd by heating camphene with dil nitric acid or by other methods d)*l-Nitrocamphene* prisms (from alc), mp 56°; was prepd by heating under reflux an alc soln of 1,7-1-bromonitrocamphene with powd Ag nitrate [Ref 1,pp 166, (88) & Ref 3] c)6-*Nitrocamphene* or sec-α-Camphene, oil, bp 119-119.5 at 14mm; was obtained (together with other products) on heating, in a sealed tube at 125-130°, tricyclene, $C_{10}H_{16}$(a tricyclic terpene) and nitric acid (d 1.075) {Ref 1,p [108] and Ref 4}
*Refs:* 1)Beil **5**, 161, 166, (85,88) & [108] 2)W.Jagelki, Ber **32**, 1499(1899) 3)M.O.Forster, JCS **79**, 646-7(1901) 4)S.Nametkin & A.Zabrodina, Ann **441**, 185(1925)
*Camphenenitrosite,* $C_{10}H_{16}N_2O_3$(?) grn oil, decomp ca 50° during distn in vacuum; was obtained by Jagelki, together with other products, on treating camphene with nitrous acid in ligroin. Its *Potassium salt,* $KC_{10}H_{15}N_2O_3$, red crysts (from alc), puffs off on heating
*Refs:* 1)Beil **5**, 161 2)W.Jagelki, Ber **32**, 1502(1899)
*Camphenenitronitrosite,* $C_{10}H_{16}N_3O_5$(?) wh pdr; mp dec ca 149°; was obtained by Jagelki, together with other products on prolonged treating of camphene with nitrous acid in ligroin
*Refs:* 1)Beil **5**, 161 2)W.Jagelki; Ber **32**, 1501 (1899)
*5-Nitroso-5-nitrocamphene or Camphenepseudo-nitrole,* $C_{10}H_{14}N_2O_3$, mw 210.23, N 13.33%; lflts(from chlf), mp 99° with decompn; was prepd by treating 6-nitrocamphene(see above) in cold, dil NaOH soln with Na nitrite and dil sulfuric acid
*Refs:* 1)Beil **5**, [108] 2)S.Nametkin & A.Zabrodina, Ann **441**, 186(1925)
*Campheneozonide,* $C_{10}H_{16}O_3$, viscous oil; was prepd by treating camphene in chlf with ozone
*Refs:* 1)Beil **5**, 160 & (84) 2)F.W.Semmler, Ber **42**, 247(1909)

**Campher.** Ger for Camphor

**Campherylazid.** Ger for Camphorylazide (see under Camphor and Derivatives)

### Camphor and Derivatives

*Camphor,* $C_{10}H_{16}O$, mw 152.23; exists in several forms, of which the most important is: *d-Camphor* or *2-Camphanone or 2-Ketocamphane* (Gum-, Japan-, Formosa- or Laurel-Camphor)(Camphre in Fr, Campher in Ger, Canfora in Ital, Alcanfor in Span & Kamfora in Rus){called 1.7.7-Trimethyl -bicyclo-[1.2.2]-heptanon-(2) in Beil},



col or wh cryst plates, easily broken when moistened with ether; mp 174-9°, bp 209.1 at 759 mm fl p 82°; slowly volatilizes in air at RT; d 0.992 at 25°/4; nearly insol in w; sol in alc, eth, chlf, $CS_2$, solvent naphtha and fixed & volatile oils. Can be obtained by distilling chips from the camphor tree(Cinamonum camphora), native of Formosa, China, Japan, Malaya, Archipelago & Brazil and now cultivated in Florida and California; can be prepd synthetically by one of the methods described in Refs 1, 5, 7, 8, 11, 12, 13)

Camphor is flammable and toxic when taken internally. It gives off flammable vapors when heated, which may form expl mixts with air (Ref 12). Sax(Ref 16) gives explosion range in air as 0.6 to 3.5% by wt of camphor, while Jono (Ref 15) gives 6 to 26% depending on conditions of testing. Toxicology of camphor is breifly discussed by Sax(Ref 16)
*Uses:* Camphor, being a good plasticizer for NC, is used in celluloids & other NC contg plastics. It is used in smokeless proplnts as a plasticizer, and as stabilizer & flash reducing agent. It has been used also in some dynamites (as desensitizer), BlkPdrs (as binder), and in some pyrotechnic compns. Camphor is now used in the following US plastic compns (Celluloids or Pyroxylin Types): a)Composition A, prepd by mixing NC(ca 11% N) 3 parts, camphor 1p, urea 0.75+0.05% of NC & solvent in amt sufficient for processing; it comes in sheets and is intended for use in powder wads & spacers; and b)Composition B, consists of NC(ca 11% N) 72-78 & camphor 28-22%; it comes with vents intended for use in fuses, tracers & primers(Ref 19)

Following are examples of the uses of camphor in proplnts & expl compns of some other countries:
*Austria-Hungary*-see Camphorated Blasting Gelatin
*France*-used camphor is some rifle proplnts, such as BFP & $BFP_1$,(Ref 6)
*Germany*-used camphor in some small arms proplnts. These proplnts were claimed to be progressive burning because their core was gelatinized NC

of high N content, which was treated on the surface with camphor w or w/o EtCentr(Ref 8a). Camphor was also used in some cannon proInts (Ref 17)

*GtBritian*-used camphor in some EC proplnts (Ref 3)

*Italy*-used a military demolition expl consisting of 100ps of 92/8-Blasting Gelatin and 5ps of camphor(Ref 4,p 310)

*Russia used* during WWI a "camphorated blasting gelatin"(which consisted of NG 90, collodion cotton 6 & camphor 4%) for filling some trench mortar shells. Compns of some camphor contg cannon proplnts are given in conf Ref 14

Accdg to Naoúm(Ref 4,p 310) the "camphorated blasting gelatin(such as Ital or Rus) required a stronger intial impulse to ensure detonation than that used for ordinary gelatin. In some cases one was required to use stronger than No 8 cap(See also Camphor, Analytical Procedures)

*Refs:* 1)Beil **7**, 101,(77) & [93] 2)Marshall **1**, (1917), 338 & **3**(1932), 98(Camphor in celluloid) 3)Marshall **2**(1917), 658 & **3**(1932), 98(Camphor in smokeless proplnts) 4)Naoúm, NG(1928), 10 & 310 4a)J.Desmaroux, MP **23**, 54-62(1928) (Fixation of camphor by NC) 5)Ullmann,**3**(1929), 60-82(Campher)(not found in new edition) 6) J.Desmaroux, MP **24**, 282-4(1930-1)(Ballistic stability of proplnts contg camphor and centralites such as the rifle proplnt BFP) 7) R.Cornubert, "Le Camphre et ces Dérivés", Masson, Paris(1933) 8)I.Gubelman & H.W.Elley, IEC **26**, 589-94(1934)(Amer production of synthetic camphor from turpentine) 8a)G.A. Hunold, SS**34**, 129(1939) 9)G.Komppa, Ber **75A**, 1-13(1942) & CA **36**, 6153(1942)(A review with 62 refs of the work done by Kompa et al on the synthesis of camphor and terpene compds) 10) Davis(1943), 257-8, 289 & 293-4 11)"Elsevier's Encyclopedia of Organic Chemistry", Elsevier, Amsterdam, series III, vol 12A(1948), 735-57 12) Kirk & Othmer **2**(1948), 808-18 13)V.Grignard et al, "Traité de Chimie Organique", Masson, Paris, vol 16(1949) 209-69(580 refs) 13a)G. Champetier & F.Boyer-Kavenoki, CR **234**,1053 (1952)(Gelatinization or NC with camphor) 14) PATR **2145**(1955),p Rus 18(Conf) 15)W.Jono, JChemSocJapan **58**, 673-5(1955) & CA **50**,8027 (1956)(Expln of camphor vapor or dust in air) 16) Sax(1957), 432 17)PATR **2510**(1958),p Ger 141 17a)Merck(1960), 200-1 18)CondChemDict(1961), 210-11 19)US Military Spec MIL-C-15567(BuOrd) (Cellulose Nitrate Plastic, for use in ammo)

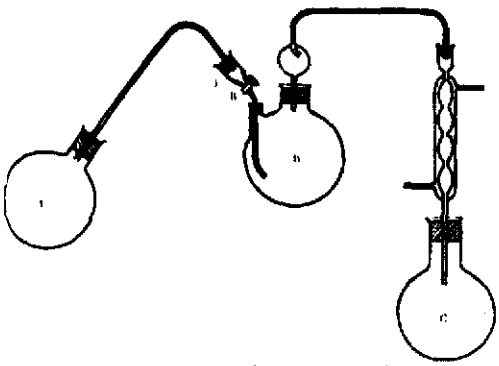
*Addnl Refs:* a)W.R.Tomlinson,Jr, PATR **1151** (1942)("Special Blasting Gelatin" developed by Hercules Powder Co of Wilmington, Del contained: mixt of NG with Tetranitrodiglycerin 90, NC 4, camphor 5 & chalk 1%. Its examination at PicArsn labs showed that it is an expl of high brisance and satisfactory stability, but very sensitive to rifle bullets and impact tests. It has a low expln temp and high volatility. Because of its sensitivity to rifle bullet and impact, it was considered to offer little promise for military use, such as for loading bombs) b)L.P.Kyrides, USP 2126560(1938) & CA **32**, 7926(1938)(Cyclohexylamine derivs as plasticizers for NC, substituting camphor)

**Camphor, Analytical Procedures.** As camphor is a widely used compd, many procedures for its detection and determination in commercial products have been developed. The general procedures are described in Refs 1,4,7 & 8, while other Refs deal with detn of camphor in expls and proplnts

Dalbert(Ref 11) who investigated existing methods of detn of camphor in proplnts, came to the conclusion that the method of Desmaroux (Ref 3) was very rapid although not as accurate as "oximation" methods described in Refs 5,6,9 & 10

The "oximation" method was modified by Dalbert to make it a semi-micro procedure which is described below

The apparatus consists of one 200-ml round bottom flask (A), one 150-ml flask (C), one 150-ml, two neck flask (B), a funnel (E) with stopcock (R), a trap and a reflux condenser for flask (C)(See Fig)



The reagents are: N/10 hydrochloric acid soln; hydroxylamine hydrochloride, prepd by dissolving 17.5g of $NH_2OH.HCl$ in mixt of 250ml alc & 25ml distd w; diethylaminoethenol, prepd by dissolving 11.7g of $(C_2H_5)_2N.CH_2.CH_2.OH$ in 1000ml alc; bromophenolblue indicator, prepd by dissolving 0.02g of $C_{19}H_{10}Br_4O_5S$ in 100 ml alc

*Standardization Procedure.* In order to det the color produced by a known amt of pure camphor, boil gently for 2hrs in a flask similar to (C), provided with reflux condenser, a mixt of accurately weighed pure camphor (20 to 30mg), 15ml distd w, 10ml hydroxylamine hydrochloride reagent, exactly 10ml of diethylaminoethanol reagent and a few pieces of pumice stone. In the 2nd flask boil a mixt of the same ingredients as above, minus camphor (blank)

The following reactions takes place with camphor in the 1st flask:

$$C_9H_{15}.CO+NH_2OH.HCl \longrightarrow C_9H_{15}.C:NOH+H_2O+HCl$$

Cool both flasks and empty their contents into two flat-bottom tubes, 32mm in diam. Bring the contents of each tube to the height of 70mm. Prepare an approximate color standard by filling another tube(the 3rd one) to the height of 70mm with the green soln prepd by mixing 50ml of 2% soln of Ni sulfate with 5ml of 1% soln of K chromate. Add to the contents of the 1st and 2nd tubes 1ml ofbromophenolindicator and titrate the 1st tube with std N/10 HCl until the color approximately matches that in the 3rd tube. Add to the contents of the 2nd tube std N/10 HCl until the color matches exactly the color in the 1st tube. The amt of camphor placed in the 2nd flask is calcd from the formula

(R'-R") x 15.2 where R' is burette reading for the 1st tube, R" for the 2nd tube and 15.2 is empirical constant

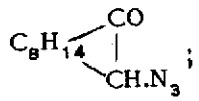
*Analysis of Sample*

a)Place in the flask (A) of apparatus(see Fig), ca 2g of accurately weighed proplnt(in small grains), 15ml NaOH soln(36°Bé), 100ml distd w, 2ml alc & a few pieces of pumice stone. Close the flask b)Place in the flask (B) 20ml distd w, 1ml sulfuric acid & a few pieces of graunlated Zn.Make connections to flasks (A) and (C) as shown in Fig and leave stopcock (R) open c)Bring the contents of (A) to boiling in order to saponify the proplnt and continue boiling until ca 60ml of liquid distls into flask (B) d)Rinse the funnel (E) with 3ml of alc, close stopcock (R) and boil the contents of (B) until ca 20ml of distillate collects in flask (C) e)Remove the stopper with the tube from the upper part of condenser and pour thru the condenser ca 10ml of alc f)For oximation of camphor contained in the distillate of flask(C), introduce 10ml of hydroxylamine hydrochloride reagent, 10ml of diethylaminoethanol reagent, a few pieces of pumice stone and boil the mixt gently for 2hrs under reflux condenser g)Cool the flask and pour its contents into a flat-bottom tube, 32mm diam used for calorimetric detns h) Proceed exactly as described in above in "Standardization Procedure", using a blank

Analytical procedures for camphor are also described in Ref 6a

*Refs:* 1)Beil **7**, 108,(79) & [98] 2)M.Marqueyrol, AnnChimAnal, **16**, 209-10(1912) & CA **6**, 667 (1912)(Approx method for detn of camphor in a proplnt by loss of wt at 30-40° of ethereal extract previously dried over sulfuric acid) 3) J.Desmaroux, MP **23**, 43-53(1928) & CA **22**, 3531(1928)(Approx detn of camphor in a proplnt by a method based on the measurement of surface tension of an aq soln of camphor removed from proplnt) 4)Ullmann, **3** (1928), 81 5)R.Vandoni & G.Desseigne, BullFr [5], **2**, 1685-91(1935) & CA **30**, 56(1936)(For volumetric detn of camphor in a proplnt or an expl by the hydroxylamine method, proceed as follows: Introduce into a 100ml flask 50ml of 2N hydroxylamine hydrochloride, 0.2ml of bromophenol blue indicator and bring to the neutral tint. Add exactly 1g of pure Ca carbonate and 1-2g of test sample. Boil on a water bath with a reflux condenser and then cool to 30°. The soln should remain alkaline to the indicator. Add a measured vol of std HCl until all Ca carbonate dissolves and finally titrate with N/1 NaOH soln. The results were claimed to be accurate to within 1% of actual camphor content) 6)G.A.Hunold, SS **34**, 129-31(1939) & CA **33**, 7113(1939) (Modification of method of Vandoni & Desseigne which was briefly described in Ref 5) 6a)Kast -Metz(1944)151-9(Props & tests) 7)Kirk & Othmer **2**(1948), 815(Specifications for camphor and required tests) 8)"Elsevier's Encyclopedia of Organic Chemistry", Elsevier, Amsterdam, vol 12A, seriesIII(1948), 754-5(General analytical procedures for camphor) 9)H.Liogier, MP **30**, 269-71(1948)(Detn of camphor in smokeless proplnts by the method of oximation) 10)G. Fleury & B.d'Estivaux, MP **30**, 273-6(1948)(Detn of camphor in rifle proplnt BFP$_1$) 11)R.Dalbert, MP **30**, 277-82(1948) & CA -not found(Detn of camphor in proplnts) 12)"Organic Analysis", Interscience, NY, vols 1-4(1953-1960)-no anal procedures for camphor are given

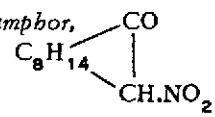
**3-Azido-d-camphor or Camphorylazide**(called Camphorylazoimide by Forster & Fierz and $\alpha$-Triazo-d-campher in Beil),



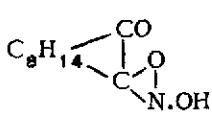
mw 193.24, N 21.75%; transparent, hexagonal prisms, (from alc) mp 67°; mildly expl at higher temps and readily volatile with steam; mod sol in boiling w & in cold abs slc; sol in ethyl acetate, acet & petr ether. Can be prepd by treating a cold aq soln of camphoryl-ψ- semicarbazide nitrate, $C_{11}H_{19}N_3O_2$ [called Pseudo-campheryl -semicarbazid-nitrat in Ger-see Beil **25**, 22 & (467)], with Na nitrite

*Refs:* 1)Beil **7**,133 2)M.O.Forster & H.E.Fierz & JCS **87**,830(1905) 3)CA-not found in years 1907 thru 1956

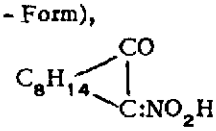
**Mononitrocamphor**, $C_{10}H_{15}NO_3$, mw 197.23, N7.10%; exists in two forms: *3-Nitro-d-camphor* or *α -Nitro-d-camphor*,



, col prisms(from benz), mp 100–3°. Other props & prepn in Ref 1; *iso-Nitro-d- camphor* (aci- Form),



or



;

was not isolated in pure state. Forms numerous salts

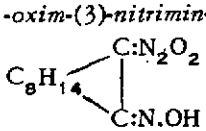
*Refs:* 1)Beil **7**,128(83) & [103] 2)Beil **7**,129,(83–4) & [103]

*Dinitro-*, $C_{10}H_{14}N_2O_5$; *Trinitro-*, $C_{10}H_{13}N_3O_7$ and *Tetranitrocamphors*, $C_{10}H_{12}N_4O_9$ were not found in Beil or in CA thru 1956

*iso-Nitrosocamphor, Oximinocamphor or Camphorquinoneoxime*, $C_{10}H_{15}NO_2$, mw 181.23, N 7.73%. Several isomers and forms are described in Beil **7**, 583, 584, 585, (325, 327) & [553,554,555]

*Pernitrosocamphor*, $C_{10}H_{16}N_2O_2$, mw 196.24, N 14.28%. Several isomers and forms are described in Beil **7**,115, 136,(81, 85) & [99]

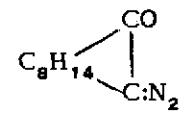
**Pernitrosoisonitrosocamphor or Camphorquinoneoxime Nitrimine** $C_{10}H_{15}N_3O_3$, mw 225.24, N 18.66%. Its isomer called [*d-Campher*]-*chinon -oxim-*(3)-*nitrimin-*(2) in Beil,



, ndls (from dil alc), mp 147.5°, was obtained by treating K salt of "pernitrosocamphor" suspended in dry ether with nitrosylchloride gas until the liq became yel. Its expl props were not reported

*Refs:* 1)Beil **7**, (332) 2)M.O.Forster et al, JCS **99**, 1989-90(1911)

**Diazocamphor**, $C_{10}H_{14}N_2O$, mw 178.23, N 15.72%. The isomer *3-Diazo-d-camphor*,



orange-yel crysts (from petr eth), mp 75°; can be prepd by diazotization of α-aminocamphor with Na nitrite in cold inorganic acid (Ref 1) or by other methods (Ref 2)) Its expl props were not reported

*Refs:* 1)Beil **7**,(332) & [557] 2)W.A.Noyes & E. Meitzner, JACS **54**,3768-73(1932) & CA **26**,5296 (1932)

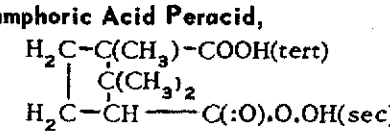
**Camphorated Blasting Gelatin.** A compn consisting of 90/10 Blasting Gelatin 96 and camphor 4% was used in Austria-Hungary as a military blasting explosive. It was replaced in 1892 by Ekrasit (Ecrasite)

*Ref:* Naoúm, NG (1928),310

### Camphoric Acid and Derivatives

*Camphoric Acid* (Camphersäure in Ger), $C_{10}H_{16}O_4$; mw 200.23. Several isomers and forms are described in Beil **9**, 745,760,(324,332) & [534,539]

**d-Camphoric Acid Peracid,**



mw 216.23, active 0 -7.40%; wh solid, mp 49-50° (in a sealed tube); expl when heated to 80-100°; fairly stable at 0° in dry air, but slowly dec at RT; sol in w(hydrolyzes in dil solns); sl sol in petr eth; sol in nearly all org solvents; was prepd by treating an ethereal soln of d- camphoric anhydride with Na peroxide in w at 0°

*Note*: When using smaller quantity of Na peroxide Dicamphoryl Peroxide is obtained

*Refs:* 1)Beil -not found 2)N.A.Milas & A.McAlevy JACS **55**,349-50(1933)

**Camphor Oil.** A constituent of crude camphor. It is usually separated into two fractions: a)*Red Oil*(also called Brown or Heavy Oil), contains fractions boiling betw 210 & 250°. Its d is 1.00 to 1.04, fl p ca 106°C and the principal constituents are: terpineol, camphor, safrole, sequiterpene hydrocarbons and alcohols b)*White* or *Light Oil*, contains fractions boiling betw 160 & 185°. Its d is .870 to .875, fl p ca 48° and the

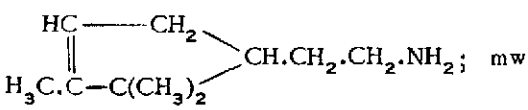
principal constituents are: terpenes, cineol with small amts of terpineol, borneol and camphor(Ref 1)

According to Ref 2, *camphor oil* is a col, natural oil with characteristic odor, d 0.870 -1.040, $n_D$ 1.465-1.481 at 20°; sol in eth, chlf; insol in alc; its chief constituents are pinene, camphor, cineol, phellandrene, dipentene, safrol & eugenol. Derived by distg the wood of the Cinamonum camphora and separating the oil from solid camphor. Used as substitute for turpentine oil in varnishes, cheap soaps, shoe polishes, etc

*Refs:* 1)Kirk & Othmer **2**(1948), 811 2)CondChem-Dict(1961), 211

**Camphorylazide.** See 3- Azido- d- camphor under Camphor

**α-Camphylamine** {called 5²-Amino-1.2.2-trimethyl-5-äthyl -cyclopenten-(2) or β-[2.2.3 -Trimethyl-$\Delta^3$-cyclopentenyl] -äthylamin in Beil},



153.26; dextrorotatory form is a liq, d 0.8688 at 20°, bp 202-4° at 760mm or 111-12° at 25mm; $n_D$ 1.47284 at 17.8°, $Q_C^V$ 1530.6 kcal/mol, $[\alpha]_D$ +3.83° at 20°. Can be prepd by reduction of α-campholenonitrile with Na in alc(Ref 3 & 4)

α-Camphylamine forms several salts, some of them are expl: a)*Perchlorate*, $C_{10}H_{19}N.HClO_4$, col crysts, mp 215°(dec); explodes at 255°(Refs 1 & 5) b)*Picrate*, no formula given, mp 194° with total decompn; sinters at 190°(Refs 1 & 2) and c)*2,4,6,Trinitro-m-cresylate*, $C_{10}H_{19}N.2C_7H_5N_3O_7$, N 15.3%, yel ndls(from w), mp 183°; expl on heating to 391° in a small tube {Ref 1,p [35] & Ref 6}

*Refs:* 1)Beil **12**, 40, (127) & [35] 2)H. Goldschmidt & L.Schulhof, Ber **19**, 711(1886) 3) F.Tiemann, Ber **29**, 3009(1896) 4)W.J.Pope & J.Read, JCS **102**, 452(1913) 5)R.L.Datta & N.R Chatterjee, JCS **115**, 1009(1919) 6)R.L.Datta et al, JACS **45**, 2432(1923)

**Canada Asbestos.** An impure *chrysotile*, a hydrated magnesium silicate $3MgO, 2Si2H_2, 2H_2O$

*Ref:* Hackh's (1944), 162 & 201

**Canada Balsam.** A yel, turpentine-like liquid from incisions in the bark of balsam fir, *Abies balsamea*, native of Canada & Maine. It dries in the air to a transparent resin which has a refractive index equal to that of glass. Hence, it is used to cement lenses together, to mount microscopic specimens, and as a varnish

*Ref:* Hackh's (1944), 162- 3

**Candelilla Wax.** See under Waxes

**Candle, in Pyrotechnics,** is an item(usually in the shape of a candle) which by its progressive combustion produces smoke or light over a comparatively long time(Ref 2). The color produced on burning of Amer pyrotechnic candles is usually green, red or yellow and the candlepower varies betw 5 & 25 thousand. For example, the candles used in Amer 250-target -identification bomb are small flares, ca 1.56" in diam and ca 11.62" long; the candlepower of its red flare is 25000, the burning time varies from 1 to 11 mins and the light is visible up to 40 miles; the candlepower of yel flare is 12000, the burning time 1 to 11 mins and visibility up to 40 miles(Ref 1)

*Refs:* 1)Anon, "Military Pyrotechnics", TM**9-1981** (1951);19-22 2)Glossary of Ord (1959),54

**Candlepower** is the luminous intensity in terms of a standard candle (a candle made of sperm wax, six to the pound, which burns 120grains of wax per hr). It is equal to 1.11 Hefner units

*Ref:* Hackh's (1944), 163

**Candlepower of Pyrotechnics Items** varies according to the items. Following are some examples: Flares aircraft, parachute 60 to 800 thousands; Flare aircraft M76 up to 850 thousand; Cartridge photoflash M112 50million; Bomb photoflash up to 800million; Candles 5 to 25 thousand; Signals aircraft 12 to 30 thousand; Signals, ground 2 to 35 thousand, Drift signals and Markers, 0.650 & 0.800 thousand and Distress signal 8 thousand

*Ref:* Anon,"Military Pyrotechnics", TM **9-1981**(1951), 16-30

**Cane Sugar or Sucrose.** See under Sugars

**Cane Sugar Octanitrate or Sucrose Octanitrate.** See Nitrosucrose under Sugars

**Canister or Case-Shot.** A special short-range antipersonnel projectile consisting of a sheet-metal,

cylindrical body and small steel or lead balls encased in a resinous matrix, but no explosive chge. When fired from a gun, the canister case disrupts just after leaving the muzzle and the balls scatter in the manner of a shotgun chge, giving effective coverage of the area immediately in front of the gun. Much used in 1812 and 1861, it was revived during WWI for use in small tank and aircraft guns and then was widely used during WWII against personnel and to clear dense undergrowth in jungle warfare(Ref 1,3,4 & 7). Accdg to Gen J.F.C.Fuller the "caseshot" was invented ca 1410

In Ref 2 are described under Artillery Ammunition:Canister, Fixed, M1, which was developed for the M1916 Gun and Canister, Fixed M2 developed for tank weapons to discourage personnel from approching the tank

In some chemical shells there is encased an ogival or cylindrical canister contg a compn which, when ignited, produces a white or colored smoke (Smoke Canister) (Ref 7). Colored Smoke Canister, M2 is briefly described in Ref 5

Following US Specifications cover requirements for various canisters

a)MIL-C-3298(Canister, colored smoke, 155-mm shell, M2)
b)MIL-C-3299(Canister, colored smoke, 155-mm shell, M3)
c)MIL-C-3297(Canister, colored smoke, 155-mm shell, M4)
d)MIL-C-3367A [Canister, smoke, for chemical shell (base ejection). Components for]
e)MIL-C-3119A(Canister, smoke, HC, 105-mm shell, M1)
f)MIL-C-3120A(Canister, smoke, HC, 155-mm shell, M1)
g)MIL-C-3121A(Canister, smoke, HC, 155-mm shell, M2)
i)MIL-C-14583(Canister, smoke, WP, 5-in proj, M5)
j)MIL-C-14585(Canister, smoke, WP, 6-in proj)

Bachem (Ref 6) patented a canister shell which, he claims, projects as nearly as possible, vertically upwards and opens in the vicinity or at the actual vertex of its trajectory, to discharge or release a flying or floating body

The term canister is also applied to that part of gas mask which contains a filter(such as activated charcoal or some chemical) for the removal of poisonous gases from the air being inhaled(Ref 7). US Specifications MIL-C-10081A, MIL-C-14113 and MIL-C-21004 cover requirements for such canisters

*Refs:* 1)Hayes (1938), 561 2)Anon "Ammunition Inspection Guide", TM **9-1904**(1944) 3)Ohart (1946), 7 & 86 4)F.W.F.Gleason, ArOrd **31**, 369 (1947) 5)Anon "Artillery Ammunition", TM **9-1901**(1950) 190 6)B.Bachem, BritP 751183 (1956) 7)Glossary of Ord (1959), 54 8)"The Macmillan Everyman Encyclopedia", NY, **3**(1959), 139-40

**Cannel Coal.** A variety of soft or bituminous coal, sufficiently hard to be cut and polished. It is rich in volatile matter (40-60%) and burns with a clear, yel, "candle-like flame. Its d is 1.2-1.3 and heat value ca 14000 BTU. It is found in England (Lancashire) and US (Cannelburg, Indiana & Jellico district, Kentucky). Has been used as a substitute for candles, as fuel in fireplaces, in metallurgy and for enriching gases obtained from other coal. Has also been used as a component of Cannel Explosives (qv)

*Refs:* 1)Kirk & Othmer **4**(1949), 89-90 & 97 2) EncyclBritannica **4**(1952), 745 3)VanNostrand's, Scientific Encyclopedia(1958), 262

**Cannel Explosives** (Poudre au cannel). Expl mixts of Amm perchlorate and cannel coal suitable for mining, patented in 1900 by Alvisi (Refs 1 & 2). The compn used in Australia contained 5ps of Amm perchlorate and 1p of cannel coal (from Scotland) (Ref 2). The compn given in Ref 3 is: Amm perchlorate 80 & cannel coal 20%

*Refs:* 1)Alvisi, BelgP 148189(1900) 2)Daniel (1902), 106 3)CondChemDict (1942), 288 (not found in later editions)

**Cannello**(Ital). Cannon Primer

**Cannello a frizione**(Ital). Friction Primer

**Cannello a percussione**(Ital). Percussion Primer

**Cannello elettrico**(Ital). Electric Primer

**Cannelure.** See under BULLETS (B.Bullets, Metal Jacketed)

**Cannizzaro, Stanislao**(1826-1910). An Italian chemist, known for his work in org chemistry and application of Avogadro's hypothesis to the atomic theory. The so-called "Cannizzaro

Reaction" involves the oxidation of one molecule of aldehyde to the salt of corresponding acid with reduction of another molecule to alcohol-by the action of concd caustic soln in presence of a catalyst:
$2RCHO+KOH \rightarrow RCOOK+RCH_2OH$
*Refs:* 1)W.A.Tilden, JCS **101**,1677-93(1912)(Cannizzaro Memorial Lecture) 2)Hackh's(1944), 163 3)Hickinbottom(1948), 189-91 4)Great Chemists (1961), 663-74

**CANNON**(Geschütz in Ger; Pièce d'artillerie or Bouche à feu in Fr; Oroodiye in Rus; Piezzo d'artiglieria or Bocca da fuoco in Ital and Pieza de artillería in Span). The term "cannon" usually includes *gun, howitzer* and *motar*, but in our opinion *recoilless gun* is also a cannon

Accdg to Amer definition, *cannon is a piece of ordnance, fixed or mobile,intended to fire projectiles of greater caliber than 0.60 inch*(Refs 11 & 16). Its Brit definition is: "a weapon of greater caliber than 1 inch" (Ref 14, v 4,p 751)

The term cannon does not include mount, but only barrel(tube), breech mechanism and firing mechanism

Accdg to Amer definition, cannons, recoilless guns, rocket launchers and guided missile launchers are classified as "pieces of artillery" or "pieces of ordnance"(Ref 16)

*Historical.* It was mentioned under Black Powder (qv), that accdg to Col Hime(Ref 2), the cannon was invented ca 1313 by an unknown German monk. There is however some evidence that Moors used, in the middle of 13th century, weapons firing large stones and darts(sieges of Seville and Niebla in Spain)(Refs 3 & 16). Gen Fuller(Ref 15) states that the earliest document that mentions a weapon resembling cannon, is the Arabic manuscript of 1304. Another Arabic manuscript written at the beginning of 14th century was located before the Russian Revolution in the Asiatic Museum of StPetersburg. One of the most interesting known ancient manuscripts describing a cannon is now preserved in the Library of Christ Church, Oxford University, England. The manuscript was written ca 1326 in Latin. It contains an illustration and a brief description of the cannon formerly called "pot de fer" or "fire-pot" and now known as the "Christ Church Gun". Accdg to some manuscripts, the Republic of Venice possessed some cannons as early as 1326(Ref 3) and that the Moors used cannons at the siege of Alicante(1331), Tarifa (1340) and Algeciras(1342)(Refs 3 & 8a)

It has been claimed by some historians, that the English used at the battle of Crécy, France(1346), three light cannons. Marshall(Ref 6) thinks that this is improbable, but Sir Charles Oman suggested(cited in Ref 15), that the cannons used at Crécy were probably *ribauldequins*, weapons invented ca 1339. They consisted of several iron tubes clamped together to form a device resembling a multiperforated cylinder. The tubes could be fired separately or simultaneously. Real cannons were used by the English at the siege of Calais(1346)

All early cannons were smooth-bore, muzzle-loaders which fired either stones or darts. The first mention of solid iron projectiles (shots) was made in 1391(Ref 15), but hollow projs filled with BkPdr(to act as an explosive) were not invented until the 16th century (Holland)(Refs 1,p 27)

Although rifled and breech-loading weapons were invented ca 16th century, they did not come into use because their manuf was too complicated for the machinery and tools existing at that period. The first successful rifled, breech-loading cannon was produced ca 1850 independently by Cavelli in Italy and by Wahrendorff in Germany. At about the same period, Whitworth in England developed a helical hexagonal-bore cannon. It was one of the weapons used during the Amer Civil War(1861-5)(Ref 16,pp 4-16)

For more detailed history of cannons see Ref 15a,pp 15-73

The following may be considered the current types of cannons:

I)**Gun**(also called Cannon)(Kanone in Ger; Canon or Canon rayé in Fr; Póoshka or Oroodiye in Rus; Cannone in Ital and Cañon in Span). It can be defined as: *a cannon with a relatively long barrel, high chamber pressure, low angle of fire and high muzzle velocity & range.* The term "gun" is also applied to all firearms and this is confusing

Modern guns are breech-loading weapons which have rifled barrels 30-40 calibers(or more) in length, capable to withstand pressures from within higher than those developed in howitzers or motars. They fire projectiles at very high muzzle velocity and with flat trajectory. Their mountings permit, usually, elevations of 20-30°, but some modern guns can fire at higher elevations(Ref 9,p 4 & Ref 11,p 2)(See also Ref 19,p 1011)

Elevation of antiaircraft guns is ca 85° and some seacoast guns ca 65°

Modern US guns may be subdivided into:
a)*Field Guns* – weapons mobile enough to accompany infantry and armored units in rapid tactial movement. They may be either towed or self-propelled(Ref 16,p 14). In Ref 9,p 173 are listed US guns, calibers 20mm to 4.5-in used during WWII and in Ref 16,pp 15-17, are given illustrations of some currently used US field guns
b)*Aircraft Guns*(Aircraft Cannons) include guns mounted inside or outside airplanes and used for air-to-air,air-to-ground or air-to-water operations. The presently used US AC gun is the 20mm Automatic Gun, but in the past, 20mm, 37mm and 75mm AC guns were used(Ref 16,pp 14 & 16)
c)*Antiaircraft Guns* are designed to fire on enemy aircraft, but can be used against other targets such as tanks. In Ref 9,p 173 are listed US guns used during WWII and in Ref 16,pp 19-20 are given illustrations of presently used 40mm, 75mm, 90mm & 120mm guns
*Note:* The guns used against tanks are called *Antitank Guns*
d)*Tank Guns* are installed in full-tracked completely armored vehicles to be used against ground targets or other tanks. In Ref 9,p 173 are listed US guns used during WWII and in Ref 16,pp 19-20 are given illustrations of presently used 76mm, 90mm & 120mm guns
e)*Railway and Seacoast Guns* were used by the US Armed Forces as late as WWII, but are not used now(Ref 20). A description of these guns was given by Hayes(Ref 7,pp 285-329) and in Ref 9,p 173 are listed the guns used during WWII. In Ref 8,pp 86-90 are given illustrations of 8in Seacoast, 8in Railway and 16in Seacoast guns. In Ref 18,pp 256-9 are listed Ger guns of WWII
f)*Naval Guns* are installed in ships. No info is at our disposal on these US guns. In Ref 18,pp 252-9 are listed some of the guns used by the Ger Navy during WWII
*Note:* Ohart(Ref 9,p 4) gives data on 37mm Field, Antiaircraft, and Antitank guns used during WWII, while Barnes(Ref 12,pp 62ff) gives illustrations and short description of guns used during WWII by the US Armed Forces

II)**Howitzer**(Haubitze in Ger; Obusier in Fr; Gaubitsa in Rus; Obice in Ital and Obús in Span). It is a weapon intermediate between gun and mortar and may be defined as: *a cannon with a length of barrel shorter, chamber pressure & muzzle velocity lower, range shorter and angle of fire higher than those of guns*

Its high angle of fire(elevation up to 65°) permits reaching targets behind hills, buildings, walls, etc, which could not be reached by direct fire from flat trajectory weapons such as guns (Ref 11,p 2; Ref 16,p 12 & Ref 19,p 1097)

Because of its relatively low muzzle velocity, a howitzer is less accurate than a gun and for this reason not recommended for use against small targets, such as tanks or aircraft. It possesses, however, the following advantages over a gun: a)Its lighter and shorter barrel permits throwing a heavier projectile than a gun of equal wt b)Its proplnt chge is not as heavy and is more flexible, and c)The life of a howitzer is much longer than that of a gun of equal caliber

All howitzers are breech-loading, rifled cannons, with barrels 20-30 calibers in length. In Ref 9,p 173 are listed US howitzers used during WWII, while in Ref 12,pp 114ff are given illustrations and some props. In Ref 16,pp 15-16 are given illustrations of presently used 75mm, 105mm, 155mm and 8in howitzers and in Ref 9,p 4 are some data on 75mm howitzers in comparaison with that on 75mm guns

The distinction betw howitzer and gun is now less marked than it was before

III)**Mortar**(Mörser in Ger;Mortier in Fr; Mortira in Rus; Mortaio in Ital and Mortero in Spanish). A mortar may be defined as: *a cannon with a barrel shorter, muzzle velocity lower, angle of fire higher and range shorter than those of howitzers*

The usual length of barrel is 10-20 calibers and angle of fire up to 85°. A mortar can reach objects behind the hills or otherwise hidden, easier than a howitzer(Ref 11,p 2; Ref 16,p 12 & Ref 19,p 1472)
*Historical:*Accdg to Greener(Ref 1,pp 17-18), mortars may be considered as derived from "Bombard"(qv), a weapon developed in the 14th century. The mortar as it is understood now was claimed to be invented in Germany ca 1435(Ref 17, v 2,p 295). Although mortars have been used for centuries, their usefulness was not fully appreciated until WWI when a highly mobile type, called "Stokes" (or "Stove") Mortar was developed. The original caliber was 60mm and it served as a prototype for other mortars, such as 81mm and 4.2in(See also below under Trench Mortar)

Majority of presently used mortars are smooth-bore, muzzle-loading weapons, but there are also some rifled-bore muzzle-loaders, some smooth-bore breech-loaders and some rifled-bore breech-loaders. As examples of rifled-bore muzzle-loaders may be cited the 4.2-in Chemical Mortar and the 914cm(36in) Mortar, nicknamed

"Little David". The latter weapon used a shell with pre-engraved band(Ref 12,pp 172-3). As examples of smooth-bore breech-loaders may be cited the 2-in Mortar of Brit design installed on some US tanks used during WWII and the 75mm Infantry Assault Mortar, M1923. As an example of rifled-bore breech-loaders may be cited the 12-in Seacoast Mortar, Model 1890, which is now obsolete(Refs 20 & 21)

Essentially, a modern smooth-bore, muzzle-loading mortar consists of a tube closed at one end with a base cap contg a firing pin. Muzzle-loaded rounds must be complete as a unit(shell with a proplnt, igniter and primer attached to the tail end) so that when they are dropped tail down into the mortar, impact with the firing pin is all that is needed to set off the propelling chge. Smooth-bore shells must have fins to stablize them in flight since rotation is absent. Besides mortars equipped only for "drop fire", there are others equipped with "combination fire" mechanism, which permits firing either by drop or by means of a trigger or by lever & lanyard arrangement(Ref 9,pp 190-4; Ref 11,pp 2 & 130-7; Ref 16,pp 160-6 and Refs 20 & 21)

Ohart(Ref 9,p 5) and Barnes(Ref 12,pp 168-74) give some data on US mortars used during WWII. In Ref 18,pp Ger 250ff are listed numerous Ger mortars of WWII. The largest weapons were 54cm "Karl" Mörser, 61cm "Thor" Mörser and 80(or 82)cm "Gustav" Geschütz

IV)**Trench Mortar**(Grabenmörser in Ger; Mortier de tranchée in Fr; Transheynaya Mortira in Rus; Mortaio di trincea in Ital and Mortero de trinchera in Span). Any mortar light enough to be easily carried and installed in trenches, foxholes, etc for firing at very high angles into enemy trenches or against other targets which are closely located from the weapon and hidden by some obstacles may be called trench mortar(Ref 20 &21)

*Note:* Trench mortar is not classified by some US authorities as a cannon. We are listing it here because it is an artillery weapon and not a small arm

Modern trench mortars were developed and used during WWI. The most known of them were the "Stokes"(60mm) and the "Brand"(45mm & 60mm) mortars. A heavier mortar (81mm) was known as "Stokes-Brand"(Ref 4,pp 129-31 & Ref 5,pp 201-5)

Ohart(Ref 9,p 5) and Barnes(Ref 12,pp 160-7) give some data on 60mm & 81mm trench mortars used by the US Armed Forces during WWII

IV)**Recoilless Gun**, misnamed *Recoilless Rifle* (Rückstossfreie Kanone in Ger; Canon sans recul in Fr; Bezotkátnaya Pooshka in Rus; Cannone senza rinculo in Ital and Cañon sin retroceso in Span). It is a cannon which permits the discharge of projectiles with no rearward movement(recoil) of barrel or mount

In these weapons, vents or orifices are located in the rear of the chamber to carry off part of proplnt gases. These orifices are openings that pass thru the breechlock,thus providing an access from the chamber to the atmosphere behind the barrel. The inside of the chamber is considerably larger than the cartridge case which is perforated and lined with heavy moisture proof paper. These perforations allow escape of gas to the sides of the chamber and then to the rear of the barrel thru the orifices. The projectiles are provided with rotating bands cut to engage the rifled bore. An overcharge of proplnt is required to achieve the same muzzle velocity as with conventional guns of the same caliber and wt of projectile(Ref 11,p 139-41 and Ref 16,pp 14 & 167-8)

These weapons are very accurate and weigh much less than conventional guns

Illustrations of presently used US recoilless guns, 57mm, 75mm, 105mm & 106mm are given in Ref 16,p 24. German recoilless guns of WWII, calibers 2cm to 15cm, are listed in Ref 18,pp 239-56

*Note:* We are including here also rocket and guided missile launchers, because they are "artillery weapons" and although they are not classified as "cannons", their functions are identical. All of them hurl missiles of larger caliber than 0.60in and for this reason cannot be classified as small arms

V)**Rocket Launcher or Rocket Projector** (Raketenwerfer, Raketenapparat or Raketenwurfmaschine in Ger; Lance-fusées in Fr; Raketnitsa or Raketnyi Starter in Rus; Apparecchio lanciarazzi in Ital and Aparato para tirar cohetes in Span). It may be defined as a device for holding, aming and firing a rocket(Ref 11,p 3 & Ref 16,p 169)

The projectiles(rockets) launched from these weapons are self-propelling, travelling toward their targets by means of gases escaping from combustion chambers within the rockets

There are two types of rocket launchers: a)*Open Tube Type Launcher* consists of one or several(Multiple Launcher) smooth-bore tubes; each equipped at the base end with an electric

firing mechanism. They may be mounted on tanks, ships, vehicles or airplanes(See Ref 13,pp 182-91)

b)*Rail Type Launcher* consists of a launching rail or beam together with elevating, traversing and equilibrating mechanisms. For example the 7.2in Multiple Rocket Launcher M17 contained 20 sets of rails enclosed within armor plate, which protected the rockets from small-arms fire(Ref 12, pp 192-3). The 8in Rocket Launcher T 53 was a simple steel framework which also served as the packing and shipping container(Ref 12,pp 194-5)

Description of some Brit rocket launchers may be found in Ref 14, v 2,p 269B & v 19,p 367D. A list of Ger WWII launchers is given in Ref 18,pp 249-59

VI)**Guided Missile Launcher** is a device to hold and aim a guided missile. There exist several types of launchers. Some are stationary(used for test purposes only), others are mobile and capable of being moved to practically any place that is accessible to conventional artillery pieces. In Ref 16,pp 173-4 are given illustrations of NIKE and CORPORAL launchers used by the US Armed Forces

More info on this subject may be obtained from the books on guided missiles

The section CANNON, etc was reviewed by A.B.Schilling of PicArsn, Dover, NJ

*Refs:* 1)W.W.Greener, "The Gun and Its Development", Cassell, Petter & Co, London (1881), 17-18 & 27 2)Col H.W.L.Hime, "The Origin Of Artillery", Longmans, Green & Co, NY (1915), 120 & 127 3)Marshall **1**(1917), 18-19 4)Anon, "History of Trench Warfare Matériel", Army Ordnance Pamphlet(1920)(available at PicArsn Museum) 5)J.H.Wallace, "The Field Artillery Journal, March-April 1932,pp 201-5 (available at PicArsn Museum) 6)Marshall **3** (1932), 1-2 7)Hayes(1938), 153-85 7a)J.H. Neuman, "The Tools of War", Doubleday, Doran & Co,NY(1943) 66-175 8)Anon, "Modern Ordnance Matériel", Raritan Arsenal, Feb 18, 1943 8a) Pérez Ara(1945), 139 9)Ohart(1946) 35 & 173 10)F.W.F.Gleason, ArdOrd **32**, 48(1947) 11)Anon, "Fundamentals of Artillery Weapons" TM **9-2305**(1947), 1-5 12)G.M.Barnes, "Weapons" of World War II", VanNostrand, NY(1947), 122-3, 125-6, 128-31, 134-5, 140-2, 144-56 & 159-74 13)A.D.Blinov, "Kurs Artillerii", Voyenizdat, Moscow, Vols 1-12(1948-1952)(available in Library of Congress) 14)EncyclBritannica **2** (1952), 464-7; **4**(1952), 751 and **19**(1952), 367D 15)Gen J.F.C.Fuller, "A Military History of the Western World", Funk & Wagnalls Co, NY, vol 1 (1954), 464 & 469-70 15a)W.Y.Carman, "A History of Firearms", StMartin's Press, NY (1955) 16)Anon, "Principles of Artillery Weapons", TM **9-3305-1**(1956), 4-8 & 12-15 17) Collier's Encycl **2**(1957), 295 18)B.T.Federoff et al, "Dictionary of Explosives, Ammunition and Weapons" (German Section), PATR **2510** (1958),pp Ger 237-59 19)Merriam-Webster's (1961), 327, 1011-12, 1097-8, 1472 & 1966 20) A.B.Schilling, PicArsn; private communication (1962) 21)H.H.Bullock, PicArsn; private communication(1962)

**Cannonites**(Canonites in Fr). Fast-burning smokeless proplnts patented ca 1889 by Chapman and manufd in England at the end of 19th century. The original compn consisted of: NC(plus small amt of graphite) 86.0, K nitrate 6.9, resin 6.2 & 0.9%(Ref 1). In Refs 2 and 3 the compn of a 30-grain type shotgun Cannonite is given as follows: NC 86.4, Ba nitrate 5.7, vaseline 2.9, lampblack 1.3, K ferricyanide 2.4 & volatile matter 1.3%

Accdg to Ref 4, Cannonite was a smokeless proplnt manufd in the 1890's by the War and Sporting Smokeless Powder Syndicate, Ltd. It consisted of : NC(mostly insol in eth-alc) 86%, some Ba nitrate and small quantities of K nitrate, charcoal, lampblack, vaseline, rosin, stearine, DNB, TNT, K ferrocyanide & graphite. For rifles the proplnt was fully colloided. The compn given in Ref 5 is nitrocotton 86, Ba nitrate 6, K ferrocyanide 2, lampblack 1 & vaselin 3%

*Refs:* 1)Daniel(1902), 106-8 2)W.Macnab & A.E. Leighton, JSCI **23**, 299(1904) 3)Marshall **1**(1917), 327 4)Marshall, Dict(1920), 18 5)CondChemDict (1942), 288(not found in later editions)

**CANNON PROPELLANT or CANNON POWDER** (Geschütztreibmittel or Kanonenpulver in Ger; Poudre pour canon in Fr; Artilleriiskii Porokh in Rus; Polvere per cannone in Ital and Pólvora para cañon in Span). US cannon propellants may be defined as compositions designed to propel heavy projectiles from artillery weapons called cannons at high velocities without causing damage to either weapon or projectile

*Historical.* Black Powder(qv) was used exclusively until about 1860's. Then, attempts

were made to replace it with smokeless proplnts made from incompletely colloided NC. These proplnts were too fast-burning for cannons(see below under Single-Base Propellants). Attempts were made to use proplnts containing picrate, such as powder of Désignole(qv) manufd in France ca 1869. In order to decrease the rate of burning of BkPdr, the completely charred carbonaceous material(charcoal) was replaced by incompletely charred material. The compn contg this material, together with K nitrate and sulfur, was known as Brown-, Chocolate- or Cocoa Powder. It was used in Europe and US betw 1880 and 1900 as proplnt for larger caliber cannons. With the development of smokeless proplnts based on fully gelatinized NC or on NC-NG, all the above cannon pdrs became obsolete(See also below under Single Base and Double Base Proplnts)

The present use of BkPdr as a proplnt is restricted to some shotguns or older types of rifles. It has also been used as an igniter of cannon proplnts but, as it produces some smoke, there is a tendency to replace BkPdr by fibrous NC. Other current uses of BkPdr are discussed under Black Powder

A good cannon proplnt should possess the following properties: a)It should be non-corrosive to cartridges or projs b)Its gases of expln should not be erosive to the barrel of a cannon c)Its burning rate should be slower than that of proplnts used in small arms in order to prevent the development of excessive pressure in the barrel, which might cause its rupture d)Its heat of expln and flame temp should not be too high in order to avoid excessive erosion of the barrel e)It should not produce bright muzzle flash and smoke visible from a great distance f)It should burn uniformerly producing the desired ballistic effect g)It should not burn degressively, but progressively except in some small caliber cannons, where neutral burning proplnts may be used and h)It should be non-hygroscopic and stable thruout long storage under a wide variety of atmospheric conditions

Grains of cannon proplnts employed in the US are usually either small single-perforated cylinders(used mostly in 20mm guns and in some howitzers) or large cylinders with seven equally spaced perforations(used in larger caliber cannons). Some rosette-shaped proplnts were used in mortars. Other shapes of grains, such as cord, flake, strip, tube, cube, tri-perforated cylinder, star-perforated cylinder and cruciform grains have been used in European countries, such as Germany(See Figs 1 & 2 and Ref 10,p Ger 146). Shapes of typical rocket proplnts (Fig 3) are given here for comparison

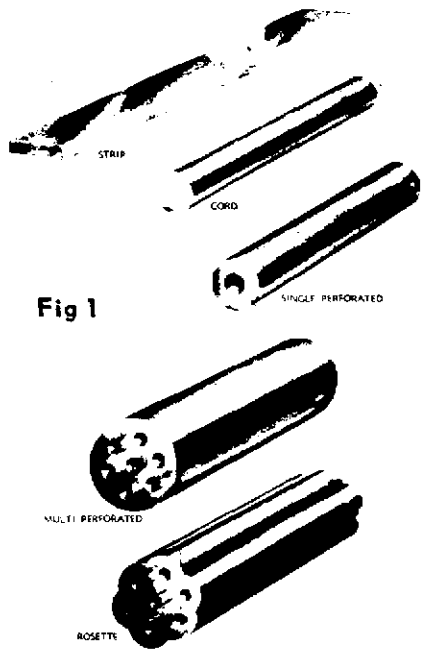



Fig 1

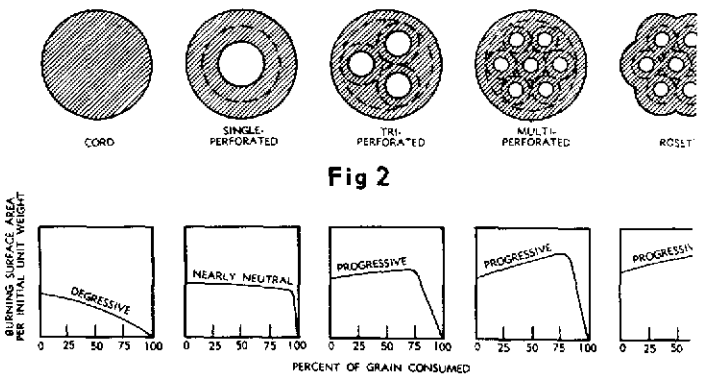



Fig 2

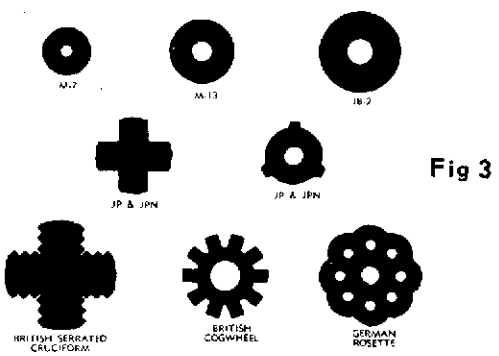



Fig 3

The size, shape, number of perforations and cross section of proplnt grains are chosen for each type of weapon so as to give the optimum burning rate for that weapon. The size of the grain determines to a great extent the burning rate of the proplnt: the larger the grain, the slower the rate of burning. As a general rule, the greater the caliber of a weapon, the larger the proplnt grain should be. In case of a multiperforated grain, the size usually refers to the *average web thickness* which is the mean of its *outer web thickness*(min dist betw the outer periphery of the grain and the wall of an outer perforation) and its *inner web thickness*(min dist betw the wall of central perforation and a wall of an outer perforation)(See Fig 4)

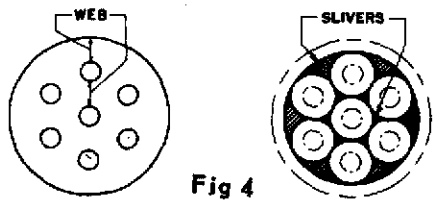



Fig 4

Diameter of perforations in a grain also influence its burning characteristics. The use of three or seven perforations in a grain is for the purpose of obtaining "progressive burning propellants", ie proplnts in which the surface area of grains increases during burning until the point is reached when nothing is left but triangular pieces, known as "silvers". These pieces of proplnt burn degressively and usually in the bore of a weapon; but if the barrel of a weapon is relatively short, some incompletely burnt slivers might be expelled from the muzzle. The rosette or Walsh grain, with a scalloped outer periphery reduces the amt of slivers produced by a multiperforated grain and therefore reduces(or even eliminates) the amt of unburnt proplnts ejected from weapons. Rosette grains were used in some US seacoast mortars(Ref 9,p 224)(See Figs 1,2 & 4)

Single-perforated grains burn in two directions and the initial diam of perforations can be so chosen that the total burning surface changes but little during burning. Such a grain is said to have "neutral" characteristics. As the surface area of grains, such as flakes, strips, cords, cubes or balls decreases continuously luring burning until the grains are completely consumed, such grains are said to burn "degressively". These grains are not very suitable for use in cannons, especially those of large caliber. Some countries such as Germany (see Ref 10,p Ger 146) and GtBritain(See Cordite) have used degressive burning proplnts in their cannons

US Specification requirements for sizes of grains used in cannon proplnts are briefly discussed under Cannon Propellants, Analytical Procedures

A table of physical forms and dimensions of typical US propellant grains is given at the end of this volume (Table IX)

As grains of cannon proplnts are rather large, it is difficult to remove from them completely(by drying) the volatile liquids(such as solvents and water) used in their manuf. This means that these proplnts contain appreciable amts of "residual volatiles" and this must be taken into consideration when considering the ballistic props and burning rates of such proplnts (Ref 9,p 225)

The relative sizes showing side and end views of typical US cannon proplnts are given in Fig 5

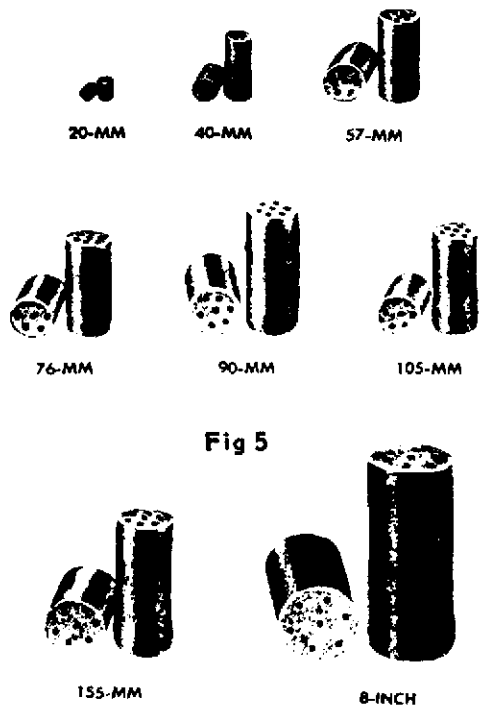



Fig 5

Accdg to compositions, cannon smokeless proplnts may be subdivided into *single-base-*, *double-base-* and *triple-base-*proplnts. The last two proplnts are sometimes called "compound" proplnts. The so-called "composite" proplnts, used in JATOS and rockets, are described under Composite Propellants

I)**Single-Base Cannon Propellants**(Nitrocellulose

Cannon Powders). Single-base proplnts intended for use in cannons are solid compns contg as a major ingredient NC, fully gelatinized by a volatile solvent(such as eth-alc) with or w/o DNT, TNT or MNN which act as auxiliary gelatinizers and as flash reducers. As minor ingredients, these proplnts contain a stabilizer(such as DPhA) with or w/o a flash reducer(such as K sulfate)

*Historical.* NC proplnts prepd before 1884, such as of Schultze(invented in Germany ca 1865),of Volkmann(invented in Austria ca 1871) and the EC (invented in England ca 1882) contained partially colloided NC(Ref 2,pp 4-5). They burned so fast that when tried in cannons, the powder chambers were either damaged or burst open

It has been generally understood, that P. Vieille of France, was the sole inventor of the modern colloidal single-base proplnt. This proplnt, known as Poudre B, was invented in 1884 [See B(Poudre) in Vol 2 of Encyclopedia]. Accdg to Brunswig(Ref 2,pp 6-7), M.von Duttenhofer of Germany, invented a similar proplnt a few months earlier than Vieille. The von Duttenhofer's proplnt was approved by German War Dept and later became known as *RCP*(Rottweiler Cellulose Pulver), because it was manufd at the Rottweil Plant of Dynamit A-G. While the compns of Fr and Ger proplnts were kept secret, some other countries worked on the same subject. In about 1891, C.E. Monroe(US) succeeded in preparing a single-base colloidal proplnt, called *Indurite*, while D.I. Mendeleev(Russia) prepd a proplnt called *Pyrocollodion.* The latter proplnt was based on NC (N=13.44%) which contained a sufficient amt of oxygen for complete combustion to CO & $H_2O$. This proplnt was adopted by the Russian Armed Forces and was used for many years

As Indurite was found to be not very suitable for use in cannons, the US Navy decided to investigate the Russian proplnt. This was done by Lt B.Bernadou, while he was stationed in StPetersburg as US Naval Attaché. B found that although Mendeleev's proplnt was satisfactory for use in cannons, better ballistic characteristics could be obtained with NC of slightly higher N content, such as ca 12.6% N.He prepd ca 1895 the proplnt by colloiding NC of N 12.6%with eth-alc and called it "Pyrocellulose Powder". It was also called "Pyrocollodion" or "Pyro" Powder, but now the word "powder" is replaced by "propellant". This proplnt was approved for service in the US Navy and the manuf started on a small scale ca 1897 for the Navy and ca 1899 for the US Army(Ref 8a). It was used during Spanish-American War(1898)

Accdg to Davis(Ref 6,p 297), the Naval Powder Factory(now called US Naval Propellant Plant), Indian Head, Md, was built in 1900, for manuf of this "Pyro" proplnt, and manuf of this proplnt at Picatinny Arsenal, Dover, NJ was started in 1907

The original US "Pyro" proplnt contained no stabilizer until ca 1909 when 0.5% of DPhA was incorporated. At the same time glazing of grains with graphite was introduced. The amt of DPhA was increased during WWI to 1%. As "Pyro" proplnts were hygroscopic, a low -hygroscopic proplnt, known as NH(Nonhygroscopic) was developed ca 1930. Its compn was: NC(13.15% N) 87, DNT 10 & DBuPh 3%. At about the same time, the proplnt called FNH (Flashless-Nonhygroscopic) was developed. Its compn was: NC(12.6% N) 74, NC(13.25% N ), 20, DNT 5 & DPhA 1%. Designations NH and FNH are not used any more, being replaced by letters M or T followed by numbers 1,2,3 etc(See Tables V,VI&VII). M means a proplnt adopted for service and T, one in the experimental stage

*Current US Single-Base Cannon Propellants.* In Table V there are listed only three proplnts (MIAI, M3D & M31) which are based on "Pyrocellulose" (NC with 12.6%N), because the majority of proplnts are now based on "Blend" (NC 13.15-13.25%N), which is prepd by mixing "Pyro" (12.6%N) with Guncotton (13.4-13.45%N). The 1st component is sol in 2:1-eth-alc, while the 2nd is not. Cannon proplnts M1, M6, M14 and recoilless gun proplnt M10 are based on NC with 13.25%N and so are small arms proplnts IMR (Improved Military Rifle) and M12 (listed here for comparison with cannon proplnts)

In above proplnts DNT acts as a gelatinizing & waterproofing agent and, being a weak expl, it contributes to ballistic characteristics. It has also a slight flash-reducing action

Accdg to Dr Walter (Ref 13), when DNT (or TNT) is incorporated, the resulting compn can be easily extruded or rolled to produce grains which are, at RT, hard but not brittle

When DNT is used for coating the grains (as in IMR & M12 proplnts), not only the proplnt becomes waterproof but also the initial rate of burning proceeds at relatively low and uniform rate

DBuPh, DEtPh & triacetin are gelatinizing, waterproofing and flash-reducing agents. K sulfate, cryolite & tin are flash-reducers, while tin also acts as a decoppering agent. DPhA and EtCentr are stabilizers and Pb carbonate an antacid. Glazing of grains with graphite is done to prevent caking in storage, to facilitate blending and loading, to improve the burning characteristics and to prevent the formation of large static chges during blending and loading

One of the single-base proplnts formerly developed at PicArsn for 90mm cannons, contained DNEtB(dinitroethylbenzene) 10, cellulose acetate 5, NC(13.15%N) 84 & EtCentr 1%. Here DNEtB acted as an expl gelatinizer, flash-reducer and waterproofing agent, while celluluose acetate was added as flash-reducer (PicArsn Specification PXS-1197)

Manuf of single-base proplnts in the US is described in Ref 5,pp 21-8, Ref 5a,pp 20-36 and Ref 6,pp 299-306

Foreign single-base proplnts are listed at the end of this section

**II)Double-Base Cannon Propellants.** This term is applied in the US to proplnts contg NC and NG as major ingredients, while in foreign countries such as Germany or Italy, the term is extended to proplnts based on NC and DEGDN(or TEGDN or Metriol Trinitrate). As minor ingredients double-base proplnts may contain stabilizers(such as EtCentr), flash reducers(such as K sulfate, cryolite or triacetin) and other ingredients(such as Ba nitrate, K nitrate, K perchlorate, carbon black and graphite)

*Historical.* The first successful double-base proplnt, called "Ballistite" (qv), was invented in 1888 by A.Nobel of Sweden(Ref 6,p 292). As this proplnt, as well as the double-base proplnt "Cordite"(qv), developed ca 1889 in Abel's laboratory, England, had very high flame temps, it was extremely erosive to gun barrels. When amts of NG in these proplnts were considerably reduced(to lower their flame temps), proplnts suitable for small caliber cannons were obtained and used during WWI & WWII in Italy, GtBritain and Germany. In the US no double-base proplnts were used in guns prior to WWII, but some were used in mortar and small arms ammo. During and after WWII some double-base proplnts have been standarized in US for use in small caliber guns and also in rockets

*Manufacture of Double-Base Propellants.* The following methods are used: a)Solvent Process -similar to that used for single-base proplnts, except that a mixt of ethanol & acetone(in lieu of ethanol-ether)is used as the solvent and the solvent recovery procedure is omitted because of the hazard involved in treating material contg NG and b)Nonsolvent of Solventless Process used when NG and any other colloiding agents constitute ca 40% of the compn. In this process the wet NC is mixed with NG and then with EtCentr. After removing the bulk of water by centrifuging, the resulting paste is put in cotton bags which are placed in dryers operated by circulating hot air. After thorough blending the remaining constituents of proplnt with partly dried paste, it is subjected to repeated rolling between steel rolls heated by circulating steam inside of them. These operations remove the rest of w and complete colloiding of NC. The thickness of the resulting sheet varies with the desired size of grains. This proplnt is called "*Solventless*" Propellant [Poudre SD(sans dissolvant) in Fr and POL (Pulver ohne Lösungsmittel in Ger]

*Properties of Double-Base Cannon Propellants.* Double-base NC-NG proplnts are considered "hot" proplnts, because their heats of expl and flame temps are much higher than those of single-base proplnts (See Tables V, VI & VII). This means that muzzle-flash and gun barrel erosion are higher with double-base than with single-base proplnts. For example, tests conducted in Germany, sometime before WWII, showed that if an average, barrel life when using single-base proplnts is ca 3500 firings, it is reduced to ca 1700 firings when using double-base proplnts

In order to make the US NC-NG proplnts "cooler" and consequently less erosive, NGu was incorporated. The resulting compns are, strictly speaking triple-base proplnts(See Table V, Proplnts M15, M17, T20, T29, M30 & M31)

SEE TABLES V-VI-VII NEXT PAGES

Accdg to info supplied by Costa & Trask of PicArsn, the thermodynamic props of cannon proplnts listed in Tables V, VI & VII were detd as follows:

A)Isochoric Flame Temperature, $T_v$, in $^oK$, from the formula $T_v = 2500 + \frac{E}{C_v}$, where E is relative energy in cal/g and $C_v$ mean heat capacity at const vol in cal/g/deg. E is the sum of values calcd for each org component from the formula

$$E = \frac{(-E)}{\text{Mol Wt}} - 132771C - 40026H - 6724N + 51.819\,O,$$

## Table V

### US Gun and Howitzer Propellants — Composition (Including Residual Volatiles) and Some C

| Propellant | M1 | M1A1 | M2 | M5 | M6 | M14 | M15 | M17 | T20 | T28E1 | T2 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Specification | MIL-P -309A | | MIL-P -323A | MIL-P -323A | MIL-P -309A | MIL-P -309A | MIL-P -668A | MIL-P -668A | | | |
| Nitrocellulose(NC) | 85.00 | 84.50 | 77.45 | 81.95 | 87.00 | 90.00 | 20.00 | 22.00 | 20.00 | 68.70 | 46. |
| (% Nitrogen in NC) | (13.15) | (12.60) | (13.25) | (13.25) | (13.15) | (13.15) | (13.15) | (13.15) | (13.15) | (13.15) | (13. |
| Nitroglycerin(NG) | – | – | 19.50 | 15.00 | – | – | 19.00 | 21.50 | 13.00 | 25.00 | 21. |
| Barium Nitrate | – | – | 1.40 | 1.40 | – | – | – | – | – | – | – |
| Potassium Nitrate | – | – | 0.75 | 0.75 | – | – | – | – | – | – | – |
| Lead Carbonate | – | – | – | – | – | – | – | – | 1.00* | – | – |
| Nitroguanidine(NGu) | – | – | – | – | – | – | 54.70 | 54.70 | 60.00 | – | 30. |
| Dinitrotoluene(DNT) | 10.00 | 10.00 | – | – | 10.00 | 8.00 | – | – | – | – | – |
| Dibutylphthalate(DBuPh) | 5.00 | 4.50 | – | – | 3.00 | 2.00 | – | – | 5.00 | – | – |
| Diphenylamine(DPhA) | 1.00* | 1.00 | – | – | 1.00* | 1.00* | – | – | – | – | – |
| 2-Nitrodiphenylamine(NDPhA) | – | – | – | – | – | – | – | – | – | – | – |
| Ethyl Centralite(EtCentr) | – | – | 0.60*** | 0.60*** | – | – | 6.00 | 1.50 | 2.00 | 6.00 | 1.5 |
| Graphite | – | – | 0.30 | 0.30 | – | – | – | 0.10** | – | 0.90 | 0.1 |
| Cryolite | – | – | – | – | – | – | 0.30 | 0.30 | – | – | 0.3 |
| Ethyl Alcohol(Residual) | 0.75 | 1.00 | 2.30 | 2.30 | 0.90 | 1.00 | 0.30 | 0.30 | 0.30 | 0.65 | 0.3 |
| Water(Residual) | 0.50 | 0.60 | 0.70 | 0.70 | 0.50 | 0.25 | 0.00 | 0.00 | 0.00 | 0.25 | 0.0 |
| Isochoric Flame Temp, $^{o}K, T_v$ | 2417 | 2225 | 3319 | 3245 | 2570 | 2710 | 2594 | 3017 | 2388 | 3132 | 322 |
| Force, ft-lbs/lb, $\times 10^{-3}$, F | 305 | 287 | 360 | 355 | 317 | 327 | 336 | 364 | 314 | 362 | 371 |
| Unoxidized Carbon,% | 8.6 | 10.0 | 0 | 0 | 6.8 | 5 | 9.5 | 3.9 | 11.6 | 1.6 | 0.6 |
| Combustibles,% | 65.3 | 73.8 | 47.2 | 47.4 | 62.4 | 58.9 | 51.0 | 38.7 | 53.1 | 56.2 | 41.7 |
| Heat of Explosion, cal/g, Q | 700 | 637 | 1080 | 1047 | 758 | 809 | 796 | 962 | 712 | 977 | 103 |
| Gas Volume, moles/g, n | 0.04533 | 0.04630 | 0.03900 | 0.3935 | 0.04432 | 0.04338 | 0.04645 | 0.04336 | 0.04794 | 0.04164 | 0.0 |
| Ratio of Specific Heats, $\gamma$ | 1.2593 | 1.2620 | 1.2238 | 1.2258 | 1.2543 | 1.2496 | 1.2557 | 1.2402 | 1.2591 | 1.2384 | 1.2 |
| Isobaric Flame Temp, $^{o}K, T_p$ | 1919 | 1763 | 2712 | 2647 | 2050 | 2168 | 2066 | 2433 | 1897 | 2529 | 261 |
| Specific Gravity, g/cc | 1.57 | 1.56 | 1.65 | 1.65 | 1.58 | 1.61 | 1.66 | 1.67 | 1.66 | 1.61 | 1.6 |
| Covolume, $in^3/lb, \eta_i$ | 30.57 | 31.22 | 27.91 | 27.52 | 29.92 | 29.54 | 31.17 | 29.50 | 30.41 | 28.74 | 28. |
| Burning Rate Characteristic of Equation $r = BP^n$ at 21°(See Note) | 0.002143 | – | 0.002432 | – | 0.002989 | – | 0.004108 | 0.006956 | – | – | – |
| Pressure Exponent, n | 0.710 | – | 0.755 | – | 0.702 | – | 0.675 | 0.632 | – | – | – |
| Loading Density, $\Delta$, g/cc | 0.1 | – | 0.1 | – | 0.2 | – | 0.2 | 0.2 | – | – | – |

*Note:* $r = BP^n$ gives rate of burning r(in/sec) as function of pressure P(psi)

*Added **Glaze added ***Diphenylamine was used before March 29, 1946

## Table VI
### US Mortar and Small Arms Propellants
### Composition (Including Residual Volatiles) and Some Characteristics

| | Mortar | | | Small Arms | | |
|---|---|---|---|---|---|---|
| Propellant | M7 | M8 | M9 | IMR | M12 | M18 *** |
| Specification | JAN-P -659 | JAN-P -381 | MIL-P -20306 | JAN-P -733 | JAN-P -528 | FA-PD -26A |
| Nitrocellulose(NC) | 54.60 | 52.15 | 57.75 | 100.00 | 97.70 | 80.00 |
| (% Nitrogen in NC) | (13.15) | (13.25) | (13.25) | (13.15) | (13.15) | (13.15) |
| Nitroglycerin(NG) | 35.50 | 43.00 | 40.00 | – | – | 10.00 |
| Potassium Nitrate | – | 1.25 | 1.50 | – | – | – |
| Potassium Perchlorate | 7.80 | – | – | – | – | – |
| Dinitrotoluene(DNT) | – | – | – | 8.00** | 8.00** | – |
| Dibutylphthalate(DBuPh) | – | – | – | – | – | 9.00 |
| Diethyphthalate(DEtPh) | – | 3.00 | – | – | – | – |
| Potassium Sulfate | – | – | – | 1.00* | 0.75 | – |
| Tin | – | – | – | – | 0.75 | – |
| Diphenylamine(DPhA) | – | – | – | 0.70* | 0.80 | 1.00 |
| Ethyl Centralite(EtCentr) | 0.90 | 0.60 | 0.75 | – | – | – |
| Carbon Black | 1.20 | – | – | – | – | – |
| Ethyl Alcohol(Residual) | 0.80 | 0.40 | 0.50 | 1.50 | 1.50 | 0.50 |
| Water(Residual) | 0.00 | 0.00 | 0.00 | 1.00 | 1.00 | 0.00 |
| Isochoric Flame Temp, $^{o}K$, $T_v$ | 3734 | 3695 | 3799 | 2835 | 2823 | 2577 |
| Force, ft-lbs/lb x $10^{-3}$, F | 368 | 382 | 382 | 331 | 331 | 319 |
| Unoxidized Carbon, % | 0 | 0 | 0 | 2.7 | 3.0 | 6.8 |
| Heat of Explosion, cal/g, Q | 1255 | 1244 | 1295 | 868 | 863 | 772 |
| Gas Volume, moles/g, n | 0.03543 | 0.03711 | 0.03618 | 0.04191 | 0.04211 | 0.04457 |
| Ratio of Specific Heats, $\gamma$ | 1.2100 | 1.2148 | 1.2102 | 1.2413 | 1.2421 | 1.2523 |
| Isobaric Flame Temp, $^{o}K$, $T_p$ | 3085 | 3042 | 3139 | 2284 | 2273 | 2058 |
| Covolume, $in^3/lb$, $\eta_i$ | – | 26.63 | 25.95 | 28.91 | 29.02 | 30.24 |
| Combustibles, % | 35.4 | 37.2 | 32.8 | 59.2 | 59.2 | 66.6 |
| Specific Gravity, g/cc | 1.69 | 1.62 | 1.60 | 1.62 | 1.62 | 1.62 |

*Added **Coating added ***Ball propellant *Note:* Small Arms Propellants are included for comparison

## Table VII
### US Recoilless Rifle Propellants
### Composition (Including Volatile Solvents) and Some Characteristics

| Propellant | M10 | T25 | M26 | T31 | T32 | T33 |
|---|---|---|---|---|---|---|
| Specification | PA-PD -123 | PA-PD -329 | OAC-PD -134 | | | |
| Nitrocellulose(NC) | 98.00 | 73.25 | 67.25 | 30.00&25.00 | 30.95&25.80 | 21.30&35.45 |
| (% Nitrogen in NC) | (13.15) | (13.15) | (13.15) | (12.20)&(13.15) | (12.20)&(13.35) | (12.20)&(13.35) |
| Nitroglycerin(NG) | – | 20.00 | 25.00 | 43.00 | 35.00 | 35.00 |
| Barium Nitrate | – | 0.75 | 0.75 | – | – | – |
| Potassium Nitrate | – | 0.70 | 0.70 | – | – | – |
| Potassium Sulfate | 1.00 | – | – | – | – | – |
| Diphenylamine(DPhA) | 1.00 | – | – | – | – | – |
| Ethyl Centralite(EtCent) | – | 5.00 | 6.00 | 2.00 | 7.95 | 7.95 |
| Graphite | 0.10** | 0.30 | 0.30 | – | – | – |
| Carbon Black | – | – | – | 0.20* | 0.30 | 0.30 |
| Ethyl Alcohol(Residual) | 1.50 | 1.20 | 1.20 | 0.50 | 0.50 | 0.50 |
| Water(Residual) | 0.50 | 0.30 | 0.30 | 0.00 | 0.00 | 0.00 |
| Isochoric Flame Temp, $^{o}K$, $T_v$ | 3000 | 3071 | 3081 | 3674 | 3100 | 3135 |
| Force, ft-lbs/lb, x $10^{-3}$, F | 339 | 353 | 356 | 387 | 366 | 368 |
| Unoxidized Carbon, % | 4 | 1.8 | 2.2 | 0 | 3.0 | 2.6 |
| Combustibles, % | 54.5 | 56.1 | 57.3 | 38.9 | 58.8 | 58.1 |
| Heat of Explosion, cal/g, Q | 936 | 962 | 966 | 1222 | 957 | 971 |
| Gas Volume, moles/g, n | 0.04068 | 0.04133 | 0.04157 | 0.03788 | 0.04246 | 0.04222 |
| Ratio of Specific Heats, $\gamma$ | 1.2342 | 1.2373 | 1.2383 | 1.2174 | 1.2419 | 1.2410 |
| Isobaric Flame Temp, $^{o}K$, $T_p$ | 2431 | 2482 | 2488 | 3018 | 2496 | 2526 |
| Covolume, $in^3/lb$, $\eta_i$ | 27.76 | 28.66 | 28.77 | 26.66 | 29.15 | 29.04 |
| Specific Gravity, g/cc | 1.67 | 1.62 | 1.62 | 1.62 | 1.62 | 1.62 |

*Added **Glaze Added

where (−E) is heat of combustion in cal/mole) and $C_v$ is calcd from the formula

$$C_v=\frac{1.62C+3.265H+3.384N+5.1930}{\text{Mol Wt}}$$

If $T_v$ is found to be over 3000°K a better approximation may be obtained from the formula

$$T_v=3000+6046\{-(C_v+0.01185)+[(C_v+0.01185)^2+3.308(10^{-4})(E-500C_v)]^{1/2}\}$$

B)Force, F, in ft-lbs/lbx$10^3$, was obtained from the formula $F=nRT_v$, where n is gas volume in moles/g and R is gas constant=1.9885 cal/degree

C)Unoxidized Carbon. This value is the calcd amt of carbonaceous smoke produced by proplnt in ballistic tests. Assumptions made to simplify calcns are as follows:

1)Proplnt gases consist only of $CO_2$, CO, $H_2O$, $H_2$& $N_2$ 2)$N_2$ gas is not involved in smoke 3)All $CO_2$& $H_2$ formed are considered as equiv amts of addnl CO & $H_2O$, without affecting fuel-oxygen balance 4)All $H_2$ is oxidized to $H_2O$, any remaining $O_2$ oxidizes someC to CO, and unoxidized C represents carbonaceous smoke

The excess (or deficiency) of oxygen in an org compd or its "oxygen balance", in percentage of $O_2$ reqd for complete conversion of C to CO and $H_2$ to $H_2O$, can be calcd from its empirical formula as follows:

$$\text{OB to CO \& } H_2O=\frac{(C+0.5H-O)\ 16x100}{MW}$$

The "unoxidized carbon" value is obtd by multiplying the oxygen balance by mw of C over the mw of O, or by 12/16. If several org substances are present, the total value is equal to the algebraic sum of individual values(See also Available Oxygen, Vol I,p A515-L)

D)Heat of Explosion, Q, in cal/g was calcd for each org component from the formula:

$$Q=\frac{(-E)-67421(2C+0.5H-O)}{\text{Mol Wt}},$$

where (−E) is heat of combustion in cal/mole

E)Gas Volume, n, in moles/g, was calcd for each org component from the formula,

$$n=\frac{C+0.5H+0.5N}{\text{Mol Wt}}$$

F)Ratio of Specific Heats, $\gamma$, was calcd from the formula

$$\gamma=1+1.987\frac{n}{C_v}$$

G)Isobaric Flame Temperature, $T_p$, in °K, was calcd from the formula $T_p=T_v/\gamma$

H)Covolume, $\eta_i$, in $in^3/lb$, was calcd for each component from the formula:

$$\eta_i=0.9\left[\frac{29.2C+7.0H+17.0N+3.80}{\text{Mol Wt}}\right]x27.7$$

The idea of *incorporating NGu* in proplnts, seems to have originated in Germany, where General U.Gallwitz developed, before WWII, the triple-base proplnt called *Gudolpulver* (See Ref 10,p Ger 143). Prior to this the Germans developed rather "cool" proplnts by replacing NG with DEGDN or TEGDN, and the Italians developed proplnts contg Metroil Trinitrate in lieu of NG. In France, H.Muraour proposed, befor WWII, a proplnt contg DEGDN 22, NC(11.9%N) 67, EtCentr 9 & K sulfate 2%

In order to make the temp of expln still lower, mono- and dinitronaphthalenes were incorporated in some Ger NC-DEGDN proplnts. The resulting compns were not as "cool" as later developed proplnts contg NGu(See under Triple-Base Propellants)

*US Double-Base Cannon Propellants.* In Tables V, VI & VII are given compns and some props of presently used proplnts. Proplnts M2, M5, M7, M8 & M9 are "standard", whereas proplnts T31, T32 & T33 are experimental. Proplnts contg NC, NG & NGu are listed here under Triple-Base Propellants (See below)

In US NC-NG proplnts, NG is used as an expl plasticizer for NC; EtCentr as stabilizer; carbon black as burning regulator; K sulfate and cryolite as flash reducers; Ba & K nitrate, as well as K perclorate(See Note below) being oxidizers, improve ignitability of proplnts(Ba salt also increases the bulk density of proplnts); 2-nitro DPhA was used as a stabilizer in lieu of DPhA which, being alkaline, was not suitable for proplnts contg NG(Ref 13). Graphite was used for the same purpose as in Single-Base Cannon Propellants

*Note:* K perchlorate used in mortar proplnt M7 (See Table VI), would be unsuitable for use in proplnts for weapons with long rifled barrels(such as guns). This is because $KClO_4$ forms, on decompn, KCl which is very erosive at high temps (Ref 13)

One of the older US mortar proplnts contained vaseline(petroleum jelly) which presumably acted as a stabilizer and flash-reducer. The compn of this proplnt was: NC(13.15%N) 54, NG 43 & vaseline 3%, with 0.5% DPhA added(US Spec 50-12-4A). Another older US cannon proplnt contained TNT and hydrocellulose. Its compn was: NC(12.6%N) 49, NG 20, TNT 20 & hydrocellulose 10%. Here TNT was added for the same purpose as DNT(See under Single-Base Cannon Propellants). Hydrocellulose was used as flash-reducer. Its "cooling" effect is due to development of large amts of gaseous products,

which are sufficiently cool to eliminate muzzle-flash, but sometimes cause formation of smoke

Foreign double-base proplnts are described at the end of this section

III)**Triple-Base Cannon Propellants.** These proplnts contain as major ingredients NC together with an "explosive oil"(such as NG, DEGDN, TEGDN or Metriol Trinitrate) and nitroguanidine (NGu), being used as a finely divided pdr dispersed thruout the NC-explosive oil colloid, contributes to ballistic potential and also acts as a cooling agent. It developes, on explosive decompn, large amts of gases which are cooler than the gases produced by NC and explosive oils. As minor ingredients of triple-base proplnts, stabilizers (such as EtCentr) and addnl flash reducers(such as K sulfate) are used

US triple-base proplnts are based on NC, NG and NGu. They are designated as M15, M17, T20, T29, T34 & T36(See Table V)

**Foreign Cannon Propellants.** The info given below mostly concerns proplnts used at the time of ca WWII:

*Argentina.* Used both single- and double-base proplnts. See Vol 1 of this Encyclopedia,p A478

*Belgium.* See Vol 2, under Belgian Explosives and Propellants

*France.* See Vol 2, under B(Poudre)

*Germany.* Used single-, double- and triple-base proplnts. See Ref 9,pp 263-4 and Ref 10,pp Ger 141-6. Gudolpulver is described in Ref 10,p Ger 81

*GrBritain.* Used nearly exclusively double-base proplnts called Cordites.Compn of a single-base proplnt is given in Ref 9,p 265 as follows: NC(13.1%N) 94.7, DNT 4.1, tin 0.5, cryolite 0.2 & EtCentr 0.5%

*Italy.* Used mostly double-base proplnts, such as Ballistite or Filite of the following compns: a) NC(12.25%N) 64.0, DEGN 35.0 & EtCentr 1% b) Nitrocellulose acetate(10%N) 63.5, DEGDN 27.0, cellulose acetate 5.0 & EtCentr 4.5% and c) NC 55.0, Metriol Trinitrate 40.5, metriol triacetate 2.0 & EtCentr 2.5%(Ref 9,p 265)(See also in Ref 8a compns Balistite ordinaria, Balistite a basso titolo, Balistite attenuata, Polvere NAC, Polvere FB, Polvere C-2 and Solenite). Compn of one of the Ital single-base cannon proplnts is given in Ref 9,p 265 as follows: NC (12.5%N) 97.0, EtCentr 2.0 & DPhA 1.0%

*Japan.* Used nearly exclusively single-base proplnts, such as: a)NC(13.1%N) 93.3, DNT 5.5, DPhA 1.0 & graphite 0.2% b)NC(13.0%N) 91.0, DNT 8.0, DPhA 0.6 & graphite 0.4% c)NC(12.5%N) 92.5, DNT 5.0, tin 2.0 & DPhA 0.5% and d) NC(12.9%N) 93.1, DNT 5.0, tin 2.0, asym-DPhU 1.5 & graphite 0.4%(Ref 9,p 266). Japanese NC was usually prepd by nitrating woodpulp. Compn of one of their double-base proplnts was: NC (11.8%N) 72.0, NG 19.5, K nitrate 2.5 & asym-DPhU 6.0%(Ref 9,p 266)

*Mexico.* Used single-base proplnts manufd at the Fábrica Nacional de Pólvoras, Santa Fé, DF (Ref 8c)

*Russia.* Used both single- and double-base proplnts, such as: a)NC(12.6 to 12.8%N) 98.7 to 99.3 & DPhA 1.3 to 0.7% and b)NC(13.1%N) 64.4, NG 20.8, DNT 3.9, vaseline 2.6, EtCentr 1.3, asym-DPhU 6.7 & graphite 0.3%(Ref 9,p 266). Compns of several Russian cannon proplnts are given in conf Ref 9a(8 unclassified refs)

*Spain.* Used single-base proplnts manufd in several Govt and private plants, such as Granada, Murcia & Galdácano(Ref 8)

*Sweden.* Used both single-base and double-base proplnts. History of development of proplnts in Sweden is described in Ref 10a, where are also given analytical procedures, but no compns of proplnts. Under "Bofors Propellants" in Vol 2 of this Encyclopedia are given formulations of some older Swedish proplnts, as well as of the newer proplnt **NK7**(Nobelkrut 7) of AB Bofors, Nobelkrut

*Switzerland.* Used both single- and double-base proplnts manufd at the Govt plant at Wimmis (Bern). The compns of current proplnts have not been revealed(Ref 8b)

*Note:* Some ingredients of foreign proplnts are not used in US compns. Examples: acardites, urethanes or camphor(as stabilizers & auxiliary gelatinizers for NC; also, when used in large amts, as flash reducers); hydrocellulose (as flash reducers); waxes(for improving ductility); Mg oxide(as antacid); graphite(not only as a glaze but also as a component uniformly distributed thruout the grains-probably to improve burning characteristics). Some Ger proplnts contained AN(as oxidizer), others dicyandiamide (as cooling agent, to decrease erosion, Ref 10,p Ger 144). One of the pre-WWII Ger proplnts contained Amm oxalate-presumably to diminish danger of ignition during extrusion(Ref 8c)

(This section was reviewed by E.Costa, R.Trask & N.Liszt of PicArsn)

*Refs:* 1)Marshall **1**(1917), 289-335 2)Brunswig (1926), 3-11 & 134-6 3)Marshall **3**(1932), 85-96 4)Stettbacher(1933), 203 4a)Pepin Lehalleur (1935), 290-1 5)Hayes(1938), 6-36 5a)Anon, "Military Explosives", TM **9-2900**(1940), 20-83 6)Davis(1943), 287-330 7)Pérez Ara(1945), 439 & 448-50 7a)Ohart(1946), 26 8)Vivas, Feigenspan & Ladreda **3**(1948), 94-225 8a)Belgrano(1952), 110-14 8b)Stettbacher, Zürich, Switzerland; private communication(1954) 8c)M.M.Kostevitch, Buenos Aires, Argentina; private communication (1954) 9)Anon, "Military Explosives", TM **9-1910**(1955), 218-66 & 329-32 9a)B.T.Fedoroff et al, "Dictionary of Russian Ammunition and Weapons", PATR **2145**(1955)(Conf), Rus 5 & 17-19 9b)Anon, "Ammunition General" TM **9-1900**(1956), 33-42 10)B.T.Fedoroff et al, "Dictionary of Explosives, Ammunition and Weapons"(German Section) PATR **2510**(1958),pp Ger 81 & Ger 140-9 10a)Anon, "Analytical Methods for Powders and Explosives", AB Bofors, Nobelkrut(1960) 11)L.Shulman, et al, "Burning Characteristics of Standard Gun Propellants at Low Temperatures(21° to -52°C)", TechRept **FRL-TR-41**, PicArsn(1961) 12)US Specifications: FA-PD-26A; JAN-P-381, JAN-P -528, JAN-P-659, JAN-P-733, MIL-P-270A, MIL-P-309A, MIL-P-323A, MIL-P-668A, MIL-P -20306, MIL-P-46489, OCA-PD-134, PA-PD-123 and PA-PD-329 13)Dr H.Walter, PicArsn; private communication(1962)

**Cannon Propellants, Analytical Procedures.** General requirements for US cannon proplnts are given in Ref 3. They are as follows:

A)*Hygroscopicity.* The amt of allowed hygroscopicity is prescribed for each individual type of proplnt in one of the Specs listed in Ref 4. Hygroscopicity is detd by weighing a 100g sample (contained in a tared dish) before and after exposure to a humid atmosphere of 90% RH and 30°, for 4 days and then each day until chge in wt betw individual weighings will be no greater than 0.2mg. This test is described in Ref 1, Method 503.2.2 and in Ref 3, Method F-4a

B)*Stability.* All single-base proplnts shall be subjected to 134.5° Heat Test and all double-base proplnts to 120° Heat Test. These tests are described in Ref 1, Method 404.1.2, Ref 2,pp 31 & 33 and Ref 3, Method F-4e. Surveillance test at 65.5° is run for information only (Ref 2,pp 30-2)

C)*Ballistic Requirements* shall be in accordance with the Ballistic Appendix to US Army Spec 50-12-3 or BurOrdSpec O-S-16666(Ref 3)

D)*Form of Grains.* For *Type I,* the grain shall be cylindrical with 7 longitudinal perforations, 1 in the center of the grain and 6 at the vertices of a symmetrical hexagon (Ref 3)

E)*Dimensions of Grains* are measured by means of a micrometer and a microscope with 25 diameters magnifications, as described in Ref 1, Method 504.1.1 and in Ref 3, Method F-4c. For Type I, the av grain length (L) shall be 2.10-2.50 times the av grain diam (D), while for Type II 3 to 6 times. For Type I, D=5 to 15 times diam of perforations (d) and For Type II D=3d

F)*Web Measurements.* For Type I, the diff betw the av outer web thickness (Wo) and the av inner web thickness (Wi) shall not exceed 15% the average web thickness (Wa) and for Type II, the av of the web measurements above the median shall not differ from the av of the total measurements by more than 15%(Ref 3)

G)*Compressibility of Grains.* When grains of Type I proplnt are subjected to a pressure sufficient to crack each grain, the av compression shall be not less than 30%. The test is described in Ref 1, Method 505.1 and in Ref 3, Method F-4d

H)*Moisture and Volatiles Determinations.* See Ref 1, Methods 101.1.2 & 101.2.2

I)*Moisture Determinations.* See Ref 1, Methods 101.3.2 & 102.1.3

J)*Volatiles Determination.* See Ref 1, Methods 103.1.3 & 103.3.3

K)*Residual Solvent.* See Ref 1, Method 103.4.1

L)*Ash.* See Ref 1, Methods 106.2.3, 106.1.2, 106.3.2 & 106.4.1

M)*Diphenylamine*(DPhA). See Ref 1, Methods 201.1.3, 201.2.3 & 201.3.3

N)*Ethyl Centralite*(EtCentr). See Ref 1, Method 202.2.2

O)*Diethylphthalate*(DEtPH). See Ref 1, Methods 203.2.2 & 203.4.1

P)*Dibutylphthalate*(DBuPh). See Ref 1, Method 204.1.2

Q)*Dinitrotoluene*(DNT). See Ref 1, Methods 205.1.2 & 205.2.3

R)*Trinitrotoluene*(TNT). See Ref 1, Methods 206.1.2 & 206.3.3

S)*Triacetin.* See Ref 1, Methods 207.4.2 & 207.5.1

T)*Nitroglycerin*(NG). Ref 1, Method 208.2.2

U)*Nitrocellulose*(NC). See Ref 1, Methods 209.2.2, 209.3.2 & 209.6.2

V)*Nitroguanidine*(NGu). See Ref 1, Methods 213.1.4, 213.2, 213.3.1 & 213.4

W)*Triethyleneglycol Dinitrate.* See Ref 1, Method 220.1

X)*Phthalate Esters.* See Ref 1, Method 221.1.1

Y)*Inorganic Salts.* See Ref 1, Methods: 303.1.3

(Potassium Perchlorate), 304.1.2(Barium Nitrate), 305.1.1(Calcium Carbonate), 306.1.3 (Tin), 306.2.2(Tin & Graphite), 306.3.1(Tin), 307.1.2(Cryolite), 308.1.3(Graphite & Carbon Black) and 309.1.2 & 310.3.1(Carbon Black)(See US Specs listed in Ref 4, for analysis of individual proplnts)

Analytical procedures used at the AB Bofors, Nobelkrut plants in Sweden are described in the Manual entitled "Analytical Methods for Powders and Explosives", Bofors(1960), pp 169-90)

(This section was reviewed by Dr H.Walter of PicArsn)

*Refs:* 1)Anon, "Propellants, Solid: Sampling, Examination and Testing", Military Standard MIL-STD-286A(1960) 2)A.J.Clear, "Standard Military Procedures for Sensitivity, Brisance and Stability of Explosives", TechRept **FRL-TR-25,** PicArsn, Dover, NJ(1961) 3)US Specification MIL-P-270A, "Powder, Propellant, Cannon 4) US Specifications: FA-PD-26A, JAN-P-381, JAN-P-528, JAN-P-659, JAN-P-733, MIL-P-270A, MIL-P-309A, MIL-P-323A, MIL-P-668A, MIL-P -20306, MIL-P-46489, OAC-PD-134, PA-PD-123 and PA-PD-329

**Canon**(Fr). Cannon

**Canon antiaérien**(Fr). AA(antiaircraft) gun

**Canon antichar**(Fr). A/T(antitank) gun

**Canon a tuyère.** Fr name for Hoch- and Niederdrukkanone, described in PATR 2510 (1958),p Ger 90

**Canon de campagne**(Fr). Field gun

**Canon de gros caliber**(Fr). Heavy gun (Large caliber gun)

**Canon de place**(Fr) Fortress cannon

**Canon de siège**(Fr). Siege cannon

**Canon lisse**(Fr). Smooth-bore cannon

**Canon obusier**(Fr). Howitzer

**Canon san recul**(Fr). Recoilless gun

**Canon torpille**(Fr). Torpedo gun

**Cañone**(Span). Cannon

**Cañone sin retroceso**(Span). Recoilless gun

**Canopus.** An older Ital perchlorate blasting expl *Ref:* U.Alvisi, Rassegna Mineraria **37**, 231(ca191 2) & CA **7**, 1974(1913)

**Canouil Powder.** A priming compn patented in England ca 1860: K chlorate 35.5, Pb hydrosulfide & Pb ferrocyanide 28.3, glass pdr 35.5 and amorphous phosphorus 0.7%. The ingredients were mixed with water to form a paste which was shaped into pellets and dried

*Refs:* 1)Cundill(1889) in MP **5**, 303(1892) 2) Daniel(1902), 108

**Capacity of Bomb or Projectiles.** The ratio of the wt of expl in a bomb or projectile to the total wt of missile, expressed in percent, is called its capacity

Aerial bombs may be subdivided into HC (high capacity) ca 80% capacity, MC(medium capacity) ca 50% and LC(low capacity) below 50%, more often 5-30%

*Ref:* A.B.Schilling, PicArsn; private communication (1962)

**Cap, Ballistic.** See Ballistic Cap

**Cap, Blasting.** See Blasting Cap

**Cap of an AP (armor-piecing) Shell.** See Vol 1,p A483

**Capexco Powder.** An older coal-mine expl: NG 32-34, Amm oxalate 30-32, Na nitrate 24-25, woodflour 8-10 & NC 0.5-1.5%

*Ref:* 1)CondChemDict(1950), 288(not listed in later editions)

**Capped Projectile.** Same as Armor-Piercing Capped(APC) Projectile. See Vol 1,p A483

**n-Caproylhydroperoxide.** Same as n-Peroxycaproic or n-Percaproic Acid

**Caprylene and Derivatives**

*Caprylene.* The compd described in Beil **1**, 221 is probably a mixt of 1-*Octene*($\alpha$-Octylene), $CH_3[CH_2]_5.CH{:}CH_2$ and 2-*Octene*($\beta$-Octylene), $CH_3.[CH_2]_4.CH{:}CH.CH_3$

*x-Mononitrocaprylene or x-Nitroöctylene,* $C_8H_{15}.NO_2$; mw 157.21, N 8.91%; liq, prepd by

nitrating caprylene with moderately strong nitric acid
*Ref:* Beil **1**, 222

**x,x-Ditrocaprylene or x,x-Dintroöctylene,** $C_8H_{14}N_2O_4$; mw 202.21, N 13.86%; liq decg on boiling; was prepd by two-stage nitration of caprylene. Its expl props were not detd
*Refs:* 1)Beil **1**, 222 2)J.Bouis, Ann Chim Phys [3] **44**, 77(1855) 3)CA 1907-1956-not found

*Tri-, Tetra- and Pentanitrocaprylenes*
-not found in Beil or in CA thru 1956

**"Cap Sensitive" Explosive** is any expl compn which can be efficiently initrated by a commercial detonating element, such as a blasting cap or detonating cord
*Ref:* Dr I.A.Grageroff, New York; private communication(1955)

**Caracteristique, Produit**(Fr). See Berthelot's Characteristic Product

**Caracteristiques des Explosifs**(Fr). See Characteristics of Explosives

## Carbamic Acid and Derivatives

*Carbamic Acid; Amidocarbonic Acid or Aminoformic Acid*(called Carbamidsäure; Kohlensäure-monoamid or Aminoameisensäure in Ger); $H_2N.COOH$; mw 61.04, N 22.95; the theoretical, first & simplest aminoacid known in aq solns, are called *carbamates,* and other derivs. The prepn & props of aq solns of carbamic acid and its salts are described in detail in Refs 1 & 2. See also Refs 3 & 4

Some of the derivs of carbamic acid are expl
*Refs:* 1)Beil **3**, 20, (9), [18] & {39} 2)Gmelin, Syst Nr **22**(1937), 868 & **23**(1936), 348-50 3) Sidgewick, OrgChem of N(1937), 272 4)V. Grignard, Edit, "Traité de Chimie Organique", Masson, Paris, vol 14(1949), 1-398(A.Guillaumin, Dérivés azotés de l'acide carbonique)

**Carbamyl Azide; Carbamoyl Azide or Azidoformamide**(called Carbamidsäureazid; Azidoameisensäureamid or Kohlensaüre-amid-azid in Ger), $H_2N.CO.N_3$; mw 86.06, N 65.10%; ndls(from ligroin), prisms(from eth), mp 92-7°, dec at 110-20°, expl on heating rapidly or in contact with Cu powd; v sol in alc; sol in w(with decompn); mod sol in eth or ligroin. Can be prepd by treating a cooled HCl sol of semicarbazide, $H_2N.CO.NH.NH_2$, either with aq $NaNO_2$ or with fumes of nitrous gases and by other methods (Ref 1). Its *Silver Salt,* $Ag_2N.CO.N_3$, wh flakes, expl violently from heat or fricyion
*Refs:* 1)Beil **3**, 129, (59), [102] & {239} 2) J.Thiele & O.Stange, Ann **283**, 37(1894) 3) C.D.Hurd & L.U.Spence, JACS **49**, 268(1927) 4)R.Hofsommer & M.Pestemer, ZElektrochem **53**, 385(1949)(UV absorption spectra)

**Mononitrocarbamic Acid**(called Nitrocarbamidsäure or Nitramid-carbonsäure in Ger), $O_2N.NH.COOH$; mw 106.04, N 26.42%; known in the form of salts, some of which expl:
*Potassium salt,* $O_2N.NK.COOK$, wh ndls, expl on heating; was prepd by nitration of urethane and subsequent hydrolysis of the nitro ester by alcoholic KOH. This salt gives, on treatment with dil acids, the expl *Nitroamide,* $H_2N.NO$(qv)
*Refs:* 1)Beil **3**, 124 & {235} 2)J.Thiele & A.Lachman, Ann **288**, 295(1895) 3)Davis(1943), 369 4)K.W.F.Kohlrausch & H.Wittek, ActaPhysAustriaca **1**, 299, 302(1948) & CA **42**, 6665(1948)(Raman spectra)

**Carbamic Acid Esters.** The general formula of these esters is $H_2N.COO.R$, where R is any alkyl or aryl radical. They can be prepd by one of the following methods: a)action of primary or secondary amines on esters of chloroformic acid; for example, methyl chloroformate & aniline yield the methyl esters of phenylcarbamic acid, or methylphenyl carbamate, $C_6H_5.NH.COO.CH_3$ b)action of alkali salts of phenol on urea chloride; for example, sodium phenate & diphenylurea, both in alc soln, yield dipthenylcarbamate, $(C_6H_5)_2N.COO.C_6H_5$ c) action of alcohols or phenols on aromatic isocyanates; for example, phenol & phenylisocyanate, when heated with a small amt of $AlCl_3$, yield phenyl phenylcarbamate, $C_6H_5.NH.COO.C_6H_5$(Ref 4)

Nathan et al(Ref 1) examined a number of carbamic acid esters and concluded that the best stabilizing action on NC is obtd with compds in which at least one H atom is replaced by an aryl radical. Davis(Refs 2 & 5) examined several comps for their gelatinizing effect on NC
*Refs:* 1)F.L.Nathan et al, BritP 12743(1912) & CA **7**, 3842(1913) 2)T.L.Davis, IEC **14**, 1140 (1922) 3)Franklin(1935), 111ff 4)Sidgewick, OrgChem of N(1937), 272 5)Davis(1943), 322

**Carbamic Acid Ethyl Esters or Urethanes**(called Carbamidsäure-äthylester or Urethan in Ger), $H_2N.COO.C_2H_5$; mw 89.09, N 15.72%; col lfts, mp 49-50°, bp 180°; sol in w, alc, eth, glycerol

or chlf; sl sol in olive oil; other props & methods of prepn are given in Beil(Ref 1)

Urethane was proposed in Germany and later in England as a stabilizer for NC(Ref 7). According to Davis(Refs 6 & 8), it is only a weak gelatinizer for NC. Nathan et al(Ref 2) prepd several metallic salts & other derivs and patented them as stabilizers & gelatinizers in NC-NG expls. According to Nathan et al(Ref 3) urethanes with two substituted H atoms, at least one of which is an aryl groups, for example, *methylphenyl urethane*, $[(CH_3)N(C_6H_5)\cdot COO\cdot C_2H_5]$ are better gelatinizers than those with only one substituted H atom. Still better results are obtd when urethane contains two aryl groups, for example, *phenyl-bensylurethane*, $[(C_6H_5)N(H_2C\cdot C_6H_5)COO\cdot C_2H_5]$ (Ref 5). Rintoul et al(Ref 5) proposed the use of *benzyl-p-tolyl-urethane*, $[(C_6H_5\cdot CH_2)N(C_6H_4\cdot CH_3)COO\cdot C_2H_5]$, and *benzylurethane*, $[(C_6H_5\cdot CH_2\cdot NH\cdot COO\cdot C_2H_5]$, as gelatinizers & stabilizers

In blasting gelatin contg at least 50% NG, one compn proposed by Rintoul et al(Ref 4) contd NG 91.6, NC 7.5, Ca $CO_3$ 0.6 & urethane 0.3%. The same inventors(Ref 5) patented propellant compns contg NC 50, NG 41, phenyl-benzylurethane 8 & diphenylurethane 1% and NC 50, NG 41, benzyl-p-tolylurethane 8.5 & ethyl-β-naphthyl ether 0.5%

*Refs:* 1)Beil **3**, 22, (9), [19] & {41} 2)Sir F.L.Nathan et al, BritP 12743(1912) & CA **7**, 3842(1913) 3)Sir F.L.Nathan et al, BritP 4941(1913); USP 1090-644(1914) & CA **8**, 1672, 2807(1914) 4)W.Rintoul & Nobel's Expl Co, BritP 14655(1915) & CA **13**, 1639(1919) 5) W.Rintoul et al, BritP 131389(1918) & CA **14**, 350(1920) 6)T.L.Davis, IEC **14**, 1140(1922) 7) Marshall **3**(1932), 99 8)Davis(1943), 322 9) CondChemDict(1961), 1195

**Nitrosocarbamic Acid Etyyl Ester; Carboethoxynitrosamine or Nitrosourethane**(called N-Nitrosocarbamidsäure-äthylester or Nitrosourethan in Ger), $ON\cdot NH\cdot COO\cdot C_2H_5$ or $HO\cdot N{:}N\cdot COO\cdot C_2H_5$; mw 11.09, N 23.72%; yel ndls(from ligroin), mp-dec ca 40° & dec completely 51-2° yielding acetaldehyde; v sol in alc, eth, MeOH & acet; sol in w; sl sol in ligroin; was obtd on reducing the Amm deriv of nitrourethane with Zn dust & AcOH (Refs 1 & 2). Davis(Ref 4) gives parts of ester required for complete gelatinization of 100ps of Pyrocellulose as 140 when dissolved in alc or 80 when in benzene

Some of its salts are expl: *Ammonium salt*, yel lfts, mp 105-20° with violent decompn; *Potassium salt*, yel powd, expl violently on heating, by friction, or when brought in contact with w; perfectly stable in dry air; and *Silver salt*, $AgC_3H_5N_2O_3$, yel powd, expl when heated; insol in w or AcOH; sol in $NH_4OH$ or mineral acids(Refs 1 & 2)

*Refs:* 1)Beil **3**, 123 & (59) 2)J.Thiele & A. Lachman, Ann **288**, 304(1895) & JCS **70I**, 208 (1896) 3)A.Hantzsch & J.Lifschitz, Ber **45**, 3030(1912)(Absorption spectra) 4)Davis(1943), 322

**Nitrocarbamic Acid Ethyl Ester; Carboethoxynitramine or Nitrourethane**, $O_2N\cdot NH\cdot COO\cdot C_2H_5$; mw 134.09, N 20.89%; lfts(from ligroin) or pltlts(from eth+ligroin), mp 64°; v sol in alc or eth; sol in w; v sl sol in ligroin; was prepd by nitration of urethane(Refs 1 & 2). Other props are given in Beil

It forms salts some of which are probably expl: *Ammonium salt*, $NH_4C_3H_5N_2O_4$, crysts(from alc), mp 171°; *Mercuric salt*, $Hg(C_3H_5N_2O_4)_2$, wh powd; *Potassium salt*, $KC_3H_5N_2O_4$, large prisms (from hot w); and *Silver salt*, $AgC_3H_5N_2O_4$, microsc ndls, mp ca 80°; very sol in alc or w (Ref 1)

*Refs:* 1)Beil **3**, 125,(59), [99] & {236} 2)J. Thiele & A.Lachman, Ann **288**, 287(1895) 3)R.N. Jones & G.D.Thorn, CanJRes **27B**, 849(1949)(UV absorption spectra)

**Carbamic Acid Methyl Ester; "Methylurethane", Methylcarbamate or Urethylan**(called Carbamidsäure-methylester or Urethylan in Ger), $H_2N\cdot COO\cdot CH_3$; mw 75.07, N 18.66%; elongated tablets, mp 52-6°, bp 176.7-77.7° at 760mm press, d 1.136 at 55.6°; other props & methods of prepn are given in Beil (Ref 1)

Its *Mercuric Hydroxide deriv*, $HO\cdot Hg\cdot NH\cdot COO\cdot C_2H_5$, prepd by treating an alc of soln of equimolar quantities of urethylan & mercuric acetate, is obtd as yel scales which dec on heating(Ref 2)

*Refs:* 1)Beil **3**, 21, (9), [18] & {40} 2)A. Pieroni, Gazz **41** II, 754(1911) & JCS **102** I, 245(1912)

**N-Chlorocarbamic Acid Methyl Ester**, $Cl\cdot NH\cdot COO\cdot CH_3$; mw 109.52, N 12.79%; crysts, mp 32°; readilysol in w or common org solvs; other props & method of prepn are given in Beil (Ref 1)

Its *Ammonium salt*, $H_4N.NCl.COO.CH_3$, is very unstable and expl spontaneously at 0°;

*Silver salt,* Ag.NCl.COO.$CH_3$, powd, defgr ca 40° but can be kept under w for several days; and *Sodium salt,* Na.NCl.COO.$CH_3$, powd, defgr ca 115°(Ref 2)
*Refs:* 1)Beil **3,** {41} 2)P.Chabrier, AnnChim (Paris) **17,** 360-62(1942); CR **214,** 363(1942) & CA **37,** 3737(1943); CA **38,** 3256(1944)

**Nitrosocarbamic Acid Methyl Ester; Carbomethoxynitrosamine or Nitrosourethylan**(called N-Nitrosocarbamidsäure-methylester or Carbomethoxydiazohydrat in Ger), ON.NH.COO.$CH_3$ or HO.N:N.COO.$CH_3$; mw 104.07, N 26.92%; yel ndls (from eth+ligroin), mp 61°(dec); v sol in w; decompd by boiling w; expl in contact with dry HCl; was prepd by treating the Amm salt of the methyl ester of nitrocarbamic acid with Zn dust & glac AcOH (Refs 1 & 2). It forms salts, some of which are expl: *Amm salt,* $NH_4C_2H_3N_2O_3$, yel powd, mp dec 105°, dec in aq soln; and *Silver salt,* $AgC_2H_3N_2O_3$, yel powd, dec quickly in light, expl on heating, by impact or friction(Refs 1 & 2)
*Refs:* 1)Beil **3,** 123 2)J.Thiele & F.Dent, Ann **302,** 251(1898) & JCS **76** I, 14-15(1899)

**Nitrocarbamic Acid Methyl Ester; Carbomethoxynitramine of Nitrourethylan,** $O_2N{\cdot}NH{\cdot}COO{\cdot}CH_3$; mw 120.07, N 23.33%; col pltlts or prisms, mp 88°, dec ca 120°-30°; was prepd by nitration of urethylan(carbamic acid methyl ester) with ethyl nitrate & $H_2SO_4$ below -5°(Refs 1 & 2) and by other methods(Ref 3)

It forms salts which are probably expl: *Ammonium salt,* $NH_4C_2H_3N_2O_4$, col ndls(from warm w); dec on boiling in w or alc $NH_3$; *Mercuric salt,* ndls(from boiling w); *Potassium salt,* $KC_2H_3N_2O_4$, ndls or prisms(from w); and *Silver salt,* $AgC_2H_3N_2O_4$, ndls, dec on boiling in alc(Ref 1)
*Refs:* 1)Beil **3,** 125(59) 2)T.Thiele & F.Dent, Ann **302,** 249(1898) & JCS **76** I, 14-15(1899) 3) H.J.Backer, Rec **31,** 12(1912)

**Carbamide.** Same as Urea

**Carbamidine.** Same as Guanidine

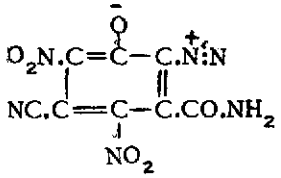
**Carbamite.** Same as sym-Diethyldiphenylurea, Centralite 1, or Ethyl Centralite(See under Centralites)

**Carbamoyl Azide.** See under Carbamic Acid

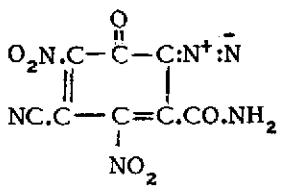
**Carbamyl or Carbamoyl.** The monovalent radical $H_2N{\cdot}CO-$ derived from carbamic acid, $H_2N{\cdot}COOH$

**Carbamyl Azide.** Same as Carbamoyl Azide

**3-Carbamyl-5-cyano-2-diazo-4,6-dinitrophenol or 3-Carbamyl-5-cyano-2-diazo-4,6-dinitrobenzoquinone** [called 4.6-Dinitro-2-diazo-phenol-dicarbonsäure-(3.5)-amid-(3)-nitril-(5) or 4.6-Dinitro-benzochinon-(1.2)-diazid-(2)-dicarbonsäure-(3.5)-amid-(3)-nitril(5) in Ger],

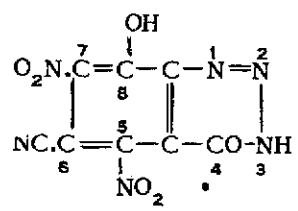


or



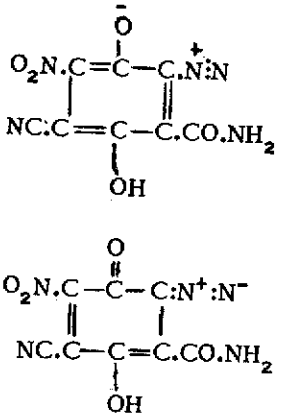
mw 278.14, N 30.22%; ref crysts(from dil AcOH), mp expl 160-65°, readily sol in alc, acet or AcOH; sl sol in hot w; insol in cold w, benz, eth, or chlf. Was obtd with other products by diazotizing isopurpuric acid, $[HO(O_2N)_2(NC)_2NHOH]$, with $NaNO_2$ & concd $H_2SO_4$ in AcOH

This compd couples with α-naphthol in an alcoholic AcOH soln to form an azo dye, which on acidification of the Na salt yields an extremely expl compd, *5,7-dinitro-8-hydroxy-4-oxy-6-cyano-3,4-dihydro*-(benzo-1,2,3-triazene), (Beil **26,** 316)



*Refs:* 1)Beil **16,** [300] 2)H.E.Fierz & H. Brütsch, Helv **4,** 2431(1921)

**3-Carbamyl-5-cyano-2-diazo-6-nitro-hydroquinone or 3-Carbamyl-5-cyano-2-diazo-6-nitro-4-hydroxybenzoquinone** [called 5-Nitro-3-diazo-hydrochinon-dicarbonsäure-(2.6)-amid-(2)-nitril-(6) or 6-Nitro-4-oxybenzochinon-(1.2)-diazid-(2)-dicarbonsäure-(3.5)-amid-(3)-nitril-(5)- in Ger]



or

mw 249.14, N 28.11%; similar in all its props to the above dinitro deriv; obtd on evaporation of the mother liquor from the prepn of the above dinitro deriv

*Refs:* 1)Beil **16,** [300] 2)H.E.Fierz & H. Brütsch, Helv **4,** 378(1921) & CA **15,** 2431(1921)

**[I(or N')-Carbamyl-III(or N)-guanyl]-triazene** [called Triazencarbonsäure-(1)-amid-carbonsäure-(3)-amidin or Triazendicarbonsäure-amid-amidin in Ger], $H_2N{\cdot}CO{\cdot}N{:}N{\cdot}NH{\cdot}C(:NH).NH_2$; mw 130.12, N 64.59%; yel ndls with $H_2O$(from hot w), mp defgr at 139° without melting, explodes at 95° on prolonged heating; readily sol in alkalies, giving a yel color; diffc sol in w. Was prepd by either neutralizing an aq soln of the hydrochloride of above triazene or gently warming the carboxylic acid ethyl ester of the above triazene, $[C_2H_5OOC\text{-}N{:}N\text{-}NH.\text{-}C(:NH).NH_2]$, with ammonia

It forms salts, some of which are expl: *Hydrochloride,* $C_2H_6N_6O$+HCl, wh crysts, mp defgr at 139° without melting, explodes at 100-110° on prolonged heating; was prepd by slowly adding diazoquanidine, $[NC.N{:}N.NH.C(:NH){:}NH_2]$, to HCl at 60-70° and *Nitrate,* $C_2H_6N_6O$+$HNO_3$, shiny crysts, mp expl at 136° without melting(Ref 1 & 2)

*Refs:* 1)Beil **3,** 128 2)J.Thiele & N.Osborne, Ann **305,** 71-4 & 77-8(1899)

**[I(or N'-Carbamyl-III(or N)-hydroxy-III(or N)-(p-aminophenyl)]-triazene** {called 3-[4-Amino-phenyl]-3-oxy-triazen-(1)-carbonsäure-(1)-amid in Ger}, $H_2N.CO.N{:}N.N(OH).C_6H_4.NH_2$; mw 195.18, N 35.89%; yel ndls(from AcOH), mp dec above 200°, expl on heating rapidly; readily sol in AcOH or dil pyridine; diffc sol in most org solvs; decompd in dil $H_2SO_4$; was prepd from p-nitrosoaniline & semicarbazide in dil AcOH

*Refs:* 1)Beil **16,** (412) 2)O.Fischer, JPraktChem **92,** 73(1915) & JCS **108,** 909(1915)

**[I(or N')-Carbamyl-III(or N)-hydroxy-III(or N)-(p-dimethylaminophenyl)]-triazene** {called 3-[4-Dimethylamino-phenyl]-3-oxy-triazene-(1)-carbonsäure-(1)-amid in Ger}, $H_2N.CO.N{:}N.N(OH).C_6H_4.N(CH_3)_2$; mw 223.23, N 31.38%; grn-yel ndls(from AcOH, dil pyridine or concd formic acid), mp expl ca 180°; sol in AcOH; sl sol in w, alc, eth or benz; was prepd from p-nitrosodimethylaniline & semicarbazide in dil AcOH with cooling(Ref 1 & 2) (See also Ref 3)

*Refs:* 1)Beil **16,** (413) 2)O.Fischer, JPraktChem **92,** 72(1915) & JCS **108,** 909(1915); **95,** 267 (1917) & JCS **112** I, 708(1917) 3)A.Angeli & Z.E. Jolles, Ber **62,** 2100(1929) & BrA **1929A,** 1290

**Carbamylic Ester.** Same as Phenyl Urethane

## Carbanilic Acid and Derivatives

*Carbanilic Acid or Phenylcarbamic Acid*(called Carbanilsäure; Phenylcarbamidsäure or Anilinoameisensäure in Ger), $C_6H_5.NH.COOH$; mw 137.13, N 10.21%; exists in the form of salts & other derivs, some of which are expl

*Ref:* Beil **12,** 319, (218) & [184]

**Carbanilic Acid Azide; Carbanilinoazide or Phenylcarbamoylazide**(called Carbanilsäureazid in Ger), $C_6H_5.NH.CO.N_3$; mw 162.15, N 34.56%; lfts(from alc + w), mp ca 103-4°(to a red liq); vol in steam; readily sol in alc, eth, chlf or benz; insol in w; other props & methods of prepn are given in Beil

*Ref:* Beil **12,** 386, (242) & [224]

**Trinitrocarbanilic Acid Esters.** Various esters, their derivs & some salts of trinitrocarbanilic acid are listed in Beil, including the ethyl & methyl esters described below

**Trinitrocarbanilic Acid Ethyl Ester or Picrylurethane**(called 2.4.6-Trinito-carbanilsäure-äthylester or Pikrylurethan in Ger), $(O_2N)_3C_6H_2.NH.COO.C_2H_5$; mw 300.19, N 18.67%; lt yel ndls (from dil alc) or pltls(from concd alc), mp 144-47°; can be prepd by nitration of carbanilic acid ethyl ester or of mono- & dinitroderivs and by other methods. Its expl props were not reported

*Ref:* Beil **12,** 768, (370) & [423]

**Trinitrocarbanilic Acid Methyl Ester or**

**Picrylurethylan**(called 2.4.6-Trinitro-carbanilsäure -methylester or Pikrylurethylan in Ger), $(O_2N)_3C_6H_2.NH.COO.CH_3$; mw 286.16, N 19.58%; almost col ndls (from alc + AcOH), mp 192-96°; was prepd by nitration of carbanilic acid methyl ester and by other methods. Its expl props were not reported
*Ref:* Beil **12**, 767 & [423]

**Carbanilide and Derivatives**

*Carbanilide; N,N' -or 1,3-or sym-Diphenylurea* (called N,N'-Diphenyl-harnstoff or Carbanilid in Ger), $C_6H_5.NH.CO.NH.C_6H_5$; mw 212.24, N 13.20%. This compd is described under BIS -COMPOUNDS as N,B'-Bis(phenyl)-urea in Vol 2 of this Encyclopedia
*Note:* N,N- or asym-Diphenylurea, called Acardite I, is described in Vol I,p A7-R

*Nitrosocarbanilide or N-Nitroso-N,N' -diphenylurea,* $C_6H_5.N(NO).CO.NH.C_6H_5$; mw 241.24, N 17.42%; yel powd, mp 82°(dec); sol in eth, alc or AcOH; dec on heating in alc or benz; other props & methods of prepn are given in Beil & in Ref 2
*Refs:* 1)Beil **12**, 583 & [312] 2)J.W.Haworth & D.H.Hey, JCS **1940**, 361-9 & CA **34**, 3699(1940)

*Dinitrosocarbanilide or N,N'-Dinitroso-N,N' -diphenylurea,* $C_6H_5.N(NO).CO.N(NO).C_6H_5$; mw 270.24, N 20.73%; yel ndls, mp dec ca 103°; sol in common org solvs; was prepd from carbanilide by the action of nitrogen oxide in AcOH or by $NaNO_2$ in concd AcOH. Other props are given in the Refs
*Refs:* 1)Beil **12**, [312] 2)H.Ryan & P.K.O'Toole, SciProcRoyDublinSoc **17**, 145-48(1923) & CA **17**, 1792(1923)

**Mononitrocarbanilide,** $O_2N.C_6H_4.NH.CO.NH.C_6H_5$; mw 257.24; N 16.34%. Three isomers are described in the literature: *2-Nitrocarbanilide,* yel ndls (from w or alc), mp 170° & 231-33° (Refs 1 & 5); *3-Nitrocarbanilide,* lt-yel ndls, mp 197.5-98.5° (Refs 2 & 4); and *4-Nitrocarbanilide,* crysts (from dil alc), mp 202-12° (Ref 3). Other props & methods of prepn are given in the Refs
*Refs:* 1)Beil **12**, 694 2)Beil **12**, 706 & [381] 3) Beil **12**, 723 4)M.S.Kharasch, JACS **43**, 1893 (1921) 5)C.Naegeli et al, Helv **21**, 1140(1938 & CA **33**, 541(1939)

**Dinitrocarbanilide,** $O_2N.C_6H_4.NH.CO.NH.C_6H_4.NO_2$; mw 302.24, N 18.54%. The three isomers are described as N,N'-Bis (monoitrophenyl)-urea under Bis(Phenyl)-urea and Derivatives

The *N-Phenyl-N'-(2,4-dinitrophenyl)-urea,* $(O_2N)_2C_6H_3.NH.CO.NH.C_6H_5$; yel ndls (from acet), mp 186-7° (dec); readily sol in acet or warm alc; sl sol in hot benz, chlf petr eth or w; diffc sol in eth; is described in Refs 1 & 2. Other dinitro derivs are listed in Ref 3
*Refs:* 1)Beil **12**, [410] 2)L.C.E.Kniphorst, Rec **44**, 719-20(1925) 3)C.Naegeli et al, Helv **21**, 1140(1938) & CA **33**, 541(1939)

**Trinitrocarbanilide,** $C_{13}H_9N_5O_7$; mw 347.24, N 20.17%. Several trinitro derivs of carbanilide are described in Refs 2 & 3. Their expl props were not reported
*Refs:* 1)Beil-not found 2)P.T.Sah & Tsu-Sheng Ma, JChineseChemSoc **2**, 159-66(1934) & CA **29**, 465(1935) 3)C.Naegeli et al, Helv **21**, 1140(1938) & CA **33**, 541(1939)

**Tetranitrocarbanilide,** $C_{13}H_8N_6O_9$; mw 392.24, N 21.43%. The N.N'-Bis (2,4-dinitro-) & N,N' -Bis (3,5-dinitrophenyl)-urea derivs are described under Bis (Phenyl)-urea and Derivatives.

The following isomers are also known: 3,3, *x,x-Tetranitrocarbanilide,* yel nds; prepd by nitration of 3,3'-dinitrocarbanilide (Refs 1 & 2); *2,4,6,3'-Tetranitrocarbanilide,* mp 164° (Ref 3); and *2,4,3',5'-Tetranitrocarbanilide,* mp 215° (Ref 3). Their expl props were not reported
*Refs:* 1)Beil **12**, 707 2)T.Curtius et al, JPraktChem **52**, 230(1895) 3)C.Naegeli et al, Helv **21**, 1141(1938) & CA **33**, 541(1939)

*Pentanitrocarbanilide,* $C_{13}H_7N_7O_{11}$; not found in Beil or in CA thru 1956

**Hexanitrocarbanilide,** $C_{13}H_6N_8O_{13}$; mw 482.24, N 23.24%. The 2,4,6,2',4',6'-hexanitro isomer or N,N'-Bis(2,4,6-trinitrophenyl)-urea is described under Bis(Phenyl)-urea and Derivatives. This compd is a high expl

**Carbanilide; N,N'-Dibutyl.** See Butylcentralite under CENTRALITES

**Carbanilide; N,N'-Diethyl.** See Centralite 1

**Carbanilide; N,N'-Dimethyl.** See Centralite 2

**Carbanilide; N-Ethyl-N'-methyl.** See Centralite 3

**Carbanilide; N-Methyl-N'-tolyl.** See Centralite 4

**Carbazid.** One of the Ger names for Carbonyl Azide or Carbonyl Diazide described in Vol I,p A528-L

**Carbazide.** A compd contg the divalent radical -NH.NH.CO.NH.NH-.*Semi-carbazide* is a compd contg the monovalent radical $H_2N.CO.NH.NH$-

## CARBAZOLE AND DERIVATIVES

*Carbazole, 9-Azafluorene, Dibenzopyrrole or Diphenyleneimine*(called Carbazol, Dibenzopyrrol or Diphenylenimin in Ger), $C_6H_4$——$C_6H_4$ (NH bridge); mw 167.20, N 8.38%; col lfts or pltlts(from xylol or by subln), mp 245°, bp 355°, d 1.10 at 18°, vap press 400mm at 323°. Carbazole is one of the principal ingredients of the anthracene fraction of coal tar distilling between 320 and 360°; it can be separated from other constituents by various methods, one of which is fusion with KOH and separation of the resulting deriv. Various methods of separating or preparing carbazole are described in Refs 1,5,7,9a,10,11,16 & others

Carbazole is a feeble base & an extremely stable compd which is unchanged on prolonged heating. It forms numerous salts & addn compds such as with perchloric acid, PA, TNB, TNT and others (Ref 1)

*Uses.* Carbazole is used as a starting material for the manuf of dyes, insecticides and, in France, as a stabilizer in NC proplnts. Accdg to Davis(Ref 6), at temps of 60 to 75°, carbazole is not as efficient a stabilizer as DPhA or Centralite but at higher temps, such as 110°, it is an excellent stabilizer(See also Ref 5a and Addnl Refs a & b)

Derivs of carbazole which are themselves expl or used in expls are described below

*Refs:* 1)Beil **20**, 433, (162) & [279] 2)T.M.Clark, IEC **11**, 204-09(1919)(Purification of catbazole; solubility in various solvs) 3)Ullamnn, 2nd ed, **3** (1929), 88-90 & 3rd ed, **5**(1954), 76-80 4)Thorpe, Supplement **1**(1934), 205 & **2**(1938), 278 4a) A.Douillet & H.Ficheroulle, MP **27**, 105-14 (1937)(Solubility curves) 5)G.T.Morgan & L.P.Walls, JSCI **57**, 358-62(1938)(Synthetic carbazole prepd by pyrolysis of o-xenylamine) 5a) R.Dalbert, MP **28**, 147-55(1938)(Comparison of stabilized NG proplnts)6)Davis(1943), 310-11 7) V.Weinmayr, USP 2350940(1944) & CA **38**, 5228 (1944)(Prepn of carbazole by heating p-amino-biphenyl & an org nitrosubstituted compd such as m-nitrobenz) 8)A.A.Morton, "Chemistry of Heterocyclic Compounds", McGraw-Hill, NY(1946), 141 9)S.J.Holt & V.Petrow, JCS **1947**, 607-11 (Properties of carbazoles, carbolines & related compds) 9a)N.Campell & B.M.Barclay, ChemRevs **40**, 359-80(1947)(Recent advances) 10)F.E. Cislak & A.L.Kranzfelder, USP 2456378(1948) & CA **43**, 1808(1949)(Prepn of carbazole by oxidn of p-aminobiphenyl in vapor phase) 11)C.Conover, USP 2479211(1949) & CA **43**, 9086(1949)(Synthesis of carbazole by oxidn of o-aminobiphenyl in presence of crysts alumina hydrate) 12)Kirk & Othmer, **5**, (1950), 26 & **7**(1951), 436,705,846 13) Karrer(1950),788 14)Elderfield **3**(1952), 291-341 15)T.E.Jordan, "Vapor Pressure of Organic Compounds", Interscience, NY(1954), Chapter **7**,p 187 & plate 14 16)W.C.Sumpter & F.M.Miller, "Heterocyclic Compounds with Indole and Carbazole Systems", Interscience, NY(1954), 70-109 17)P.Tavernier & M.Lamouroux, MP **39**, 355(1957)(Thermochem values) 18)Sax(1957), 435(Toxicity) 19)CondChemDict(1961), 215 20) US Spec MIL-C-13613(Ord)

*Addnl Refs:* a)W.H.Rinkenbach, PATR **1480**(1944) (Study of various stabilizers for single-base proplnts showed that carbazole and Methylacardite are inferior to DPhA & Methylcentralite) b) P.F.Macy, PATR **1641**(1947)(Study of various stabilizers for double-base proplnts showed that carbazole, Acardite I & EtCentr are superior to DPhA)

**Carbazole, Analytical Procedures.** Carbazole gives with isatin in concd sulfuric acid a blue coloration(Ref 1). As an indole derivative, it gives a positive "pine-splinter test"(formation of a red color when a pine-splinter soaked in HCl soln is held in the vapor of an alc soln of carbazole)(Refs 1a, 2 & 8). Carbazole may also be identified by a bluish-green coloration produced when a trace of carbazole is dissolved in concd sulfuric acid and a drop of nitric acid is then added(Ref 8,p 72). Various other colorimetric tests for carbazole are known, such as described in Refs 1,1a,2,5 & 6 and Addnl Refs a,e,g,h & m

Carbazole may also be identified as its picrate(red ndls, mp 185°), its addn compd with styphnic acid(crysts, mp 178.5-179.5°)(Ref 8,p 71) or its addn compd with 1,3,5-TNB, mp ca 200.5° (Addnl Ref n)

When carbazole is used in proplnts together with DPhA, it may be detected by dissolving the mixt in benz, carefully adding(without mixing), a few drops of 70% sulfuric acid and then 1 drop of 3% hydrogen peroxide. If carbazole is present, a green tinge appears at the interface of the two

layers

Coulson & Biddiscombe(Ref 4) examined the following methods for quantitative detn of carbazole: a)Method based on an estimation of nitrogen by Kjeldahl's process(such as described in Addnl Ref f) b)Cohns method based on the acetylation of carbazole, with subsequent titration of excess AcOH(Ref 1,p 31) c)Method based on quantitative separation of carbazole as the N -potassium dervative, followed by its decompn and weighing the recovered carbazole(Ref 4,p 46) and d)Ardsahev's method of bromination (Addnl Ref a). They came to the conclusion that none of these methods is satisfactory. They also examined the nitrosation method of Khmelevskii & Postovskii(Ref 3) and found it satisfactory. In this method the sample contg carbazole is treated with nitrous acid(generated from Na Nitrite & AcOH) and the excess of nitrous acid is decompd to produce NO, which is swept out in a stream of carbon dioxide into strong KOH soln and its vol measured

C & B slightly modified the method of Kh & P, and gave its detailed description(Ref 4,pp 47-51) (Compare with Addnl Ref k)

Ovenston(Ref 5 & 6) described the chromotographic method of detng carbazole in expls and proplnts. As the streak reagent, he used a 0.5% soln of K dichromate in 60% sulfuric acid which causes carbazole to turn green. A paperchromatographic detn of carbazole is described in Addnl Ref l

A gasometric method for detg carbazole is described in Addnl Ref d and an infrared absorption spectra method in Addnl Ref i

A chromatographic analysis of proplnts contg derivs of carbazole, such as nitro-, nitroso-, nitronitroso-, and dinitro- is described in Ref 7

Requirements of the US Armed Forces for carbazole, used as a primary material for manufg TeNCbz (tetranitrocarbazole) are covered by Specification MIL-C-13613(Ord), superseding PA -PD-185(Ref 1). The requirements are: a)*Purity* -97.0%, minimum(when detd by Kjeldahl method, as specified in proced 4.4) b)*Freezing Point* 244.0°, min(when detd as specified in 4.5) *Note:* The app and procedure are similar to those given in Vol 1,pp A612-R & A613-L c) *Ash Content*-0.10% max(when detd by incinerating a 10g sample in a muffle furnance, as specified in 4.6) d)*Moisture Content*-0.10%, max(when detd by heating a 5g sample at 100-105° to const wt (ca 2hrs) as specified in 4.7) e) *Color* white to greyish-wh(when detd by visual inspection, as specified in 4.8)

*Refs:* 1)Beil **20**, 435 & [281] 1a)G.Cohn "Die Carbazolgruppe", Thieme, Leipzig(1919), 31 & 43 2)Thorpe, **2**(1938), 278 3)V.Khmelevskii & I.Ya.Postovskii, ZhPriklKhim **17**, 463-70(1944) & CA **39**, 3651(1945) 4)E.A.Coulson & D.P. Biddiscombe, Analyst **74**, 46-51(1949)(7 refs) & CA **43**, 3746(1949) 5)T.C.J.Ovenston, JCSI **68**, 54-9(1949) & CA **43**, 5593(1949) 6)T.C.JOvenston, Analyst **74**, 344-51(1949) & CA **43**, 8138(1949) 7)W.A.Schroeder et al, IEC **43**, 941-3(1951) 8) W.C.Sumpter & F.M.Miller, "Heterocyclic Compounds with Indole and Carbazole Systems", Interscience, NY(1954), 71-2 9)Organic Analysis, Interscience, NY, vols 1,2,3 & 4-not found

*Addnl Refs:* a)B.I.Ardashev, ZhPriklKhim **10**, 1032-41)(1041 in Fr)(1937) & CA **32**, 1612(1938); RusP 52893(1938) & CA **34**, 5378(1948)(Detn of carbazole by titrating its AcOH soln with bromide-bromate reagent until the blue coloration of I-starch paper remains for 10mins) c)M.Il'inskii & R.B.Roshal, DoklAkadN **17**, 117-20(1937)(in Ger) & CA **32**, 5335-6(1938) [Detn of carbazole by treating with formaldehyde to form β-(hydroxymethyl) -carbazole] d)V.Khmelevskii & I.S.Levin, Prom-OrgKhim **7**, 308-10(1940) & CA **35**, 3925(1941) (Gasometric method for the detn of carbazole in crude anthracene) e)D.G.Harvey et al, JCS **1941**, 154-5 & CA **35**, 4769(1941)(Carbazole in presence of 2,3,4,5- -tetrahydro-β-carboline-4-carboxylic acid in concd $H_2SO_4$ produces a permanent dark green coloration) f)E.Ruterberg, Bodenkunde u Pflanzenrähr **26**, 97-105(1941) & CA **37**, 3013(1943) (Detn of nitrogen in carbazole by a modified Kjeldahl procedure) g)V.Arreguine, RevUnivNacl, Córdoba, Argentina **31**, 1706-9(1944) & CA **39**, 3222(1945)(Colorimetric method of detg carbazole using xanthydrol in AcOH-HCl soln) h)N.Strafford & W.L.Stubbins, Rec **67**, 918-26(1948) & CA **43**, 3747(1949)(Detn of carbazole by means of salicylaldehyde reagent; a blue coloration is produced) j)A.Pozefsky & I.Kukin, AnalChem **27**, 1466-8(1955) & CA **50**, 6257(1956)(Group-type nitrogen-hydrogen analysis of pyrrole-indole -carbazole type compds by an infrared absorption method) k)E.Omori, NipponKagakuZasshi **77**,152 -4(1956) & CA **51**, 17613(1957)(Quantitative analysis of refined carbazole by nitrosation) l) T.Wieland & W.Kracht, AngChem **69**, 172-4(1957) & CA **52**, 173(1958)(Paperchromatographic analysis of mixts contg carbazole) m)G.Vanags & M.Mackanova, ZhAnalKhim **13**, 485-6(1958) & CA **53**, 4022(1959)(Color reaction of carbazole with

2-nitro-1,3-indandione) n)J.C.Godfrey, AnalChem **31** 1088(1959) & CA **53**, 15716(1959)(1,3,5-TNB may serve as a quantitative reagent for carbazole because it forms a definite complex, mp 200.5° and mol wt ca 380)

**3-Azidocarbazole or Carbazole-3-azoimide,** $C_6H_4$——$C_6H_3.N_3$ (NH); mw 208.22, N 26.91%; lustrous col plates(from eth, alc or ligroin), becoming brn on exposure to light, mp 176-77(dec with violent evoln of gas); readily sol in common org solvs; was prepd by treating carbazol-3 -diazonium chloride with an aq soln of $NaN_3$. When this compd is brought in contact with concd $H_2SO_4$, it decomposes with expl violence
*Refs:* 1)Beil **20**, [290] 2)G.T.Morgan & H.N. Read, JCS **121** III, 2714-15(1922)

**3-Diazocarbazole or Carbazole-3-diazoimine,** $C_6H_4$——$C_6H_3$:$N_2$ (N); mw 193.20, N 21.75%; bright orn-red ndls, decomp rapidly on exposure to light; mp darkness at 80-90° & expl at 95°(when heated rapidly), but when the temp is raised slowly, it begins to darken at 80°, becomes brn at 105° and does not melt even at 300°; dissolves in w with a deep red coloration; attempts to recrystallize it from w resulted in decompn & formation of a brn ppt. It was first prepd by Ruff & Stein(Ref 2) by treating an aq soln of carbazole -3-diazonium chloride with concd NaOH. The compd first separated as a red oil and then turned into red ndls which were very expl & extremely sensitive to light. This compd was not properly identified by Ruff & Stein(Ref 2). Morgan & Read (Ref 3) prepd the compd later by the same method and properly identified it

3-Diazocarbazole expl on heating, by impact or by friction. It must be stored in the dark as the compd is extremely sens to light
*Refs:* 1)Beil **21**, [279] 2)O.Ruff & V.Stein, Ber **34**, 1681(1901) 3)G.T.Morgan & H.N.Read, JCS **121** II, 2712(1922)

**Carbazole-3-diazonium Hydroxide and Its Salts,** $C_6H_4$——$C_6H_3.N_2.OH$ (NH); mw 211.22, N 19.90%. The hydroxide exists only in soln which decomposes rapidly on exposure to light; was obtd by diazotizing 3-aminocarbazole with $NaNO_2$ & HCl(Refs 1,2 & 3)

Some of its salts which are unstable and expl include: *Carbazole-3-diazonium Bromide,* $C_{12}H_8N_3.Br+2H_2O$, yel ndls(from w), mp 110° (dec)(Ref 4); *Carbazole-3-diazonium Chloride,* $C_{12}H_8N_3.Cl+2H_2O$, yel ndls(from w), mp becomes grn at 98° & dec at 102°; the *Anhydrous Chloride Salt,* $C_{12}H_8N_3.Cl$, orn-yel crysts, darkens at 106-10° and decomposes explosively ca 153° (Refs 3 & 4); *Carbazole-3-diazocyanide,* $C_6H_4$——$C_6H_4.N_2.CN$ (NH), brick-red ndls(from 50% alc), becomes brn on exposure to light, mp dec ca 155-60°, insol in common org solvs(Ref 3); *Carbazole-3-diazonium Iodide,* $C_{12}H_8N_3.I+H_2O$, yel crysts, become grn ca 73°, & decomp explosively ca 81°(Ref 4); and *Carbazole-3-dizonium Nitroprusside,* $(HN{:}C_{12}H_7N_2)_2[Fe(CN)_5(NO)]$, lt yel ppt, becomes brn on exposure to light, mp-when heated rapidly turn grn ca 150° and decomp with expl at 160°(Ref 3)
*Refs:* 1)Beil **22**, 590 [502,517] 2)O.Ruff & V.Stein, Ber **34**, 1668, 1680(1901) 3)G.T.Morgan & H.N.Read, JCS **121** II, 2711-14(1922) 4)S.H.Tucker, JCS **125** I, 1145-48(1924)

**Nitrated Compounds of Carbazole**

The nitration of carbazole with nitric acid of various strengths and at various temps or by the use of $H_2SO_4$ & $HNO_3$, produces nitrocarbazoles of various degrees of nitration. Many refs are available on the nitration of carbazole but particular attention is called to Refs 7,12 & 14. Some of the nitrated derivs of carbazole described in the literature are the following:
*9 or N-Nitrosocarbazole,* $C_6H_4$——$C_6H_4$ (N—NO); mw 196.20, N 14.28%, yel shinny ndls(from alc), mp 82°(Ref 1); *3-Nitrosocarbazole,* listed in Refs 5 & 12 but no info on props available; *1-Nitrocarbazole* $C_6H_4$——$C_6H_3.NO_2$ (NH), mw 212.20, N 13.20%, yel ndls(from glac AcOH), mp 187°(Ref 2); *2 -Nitrocarbazole,* yel ndls(from benz with charcoal), mp 166-73°(Refs 6 & 8); *3-Nitrocarbazole,* yel crysts(from xylol), mp 205-14°(Ref 3); *4 -Nitrocarbazole,* yel-orn plates(sublimation), mp 179-83°(Refs 6 & 8); *9-Nitroso-3-nitrocarbazole,* $C_6H_4$——$C_6H_3.NO_2$ (N—NO), mw 241.20, N 17.42%, lt yel ndls(from alc), mp 166-69(dec)(Ref 4); *1,6 -Dinitrocarbazole,* $O_2N.C_6H_3$——$C_6H_3.NO_2$ (NH), mw 257.20, N 16.34%, wh crysts, mp-chars betwn

300-60° without melting; claimed to have been isolated & probably identified from chromatographic props by Schroeder et al(Ref 9); *2,6-Dinitrocarbazole,* yel ndls(from acet), mp 329-30°(dec), detailed description of prepn given by Leditschke(Ref 11); same compd called "3,7 -Dinitrocarbazole", mp 325-6°, by Smith & Brown(Ref 10); *3,6-Dinitrocarbazole,* yel ndls (from nitrobenz), mp-darkens at 280 & melts ca 335°(Ref 4); *2,7-Dinitrocarbazole,* yel ndls(from acet), mp 335-42°(Refs 10 & 11); *1,3 -Dinitrocarbazole,* crysts(from xylene), mp 263°, was prepd by heating 1-(2,4-dinitrophenyl) -benzotriazole & m-DNB 1hr at 270-90° in a salt -bath(Graebe-Ullmann synthesis)(Ref 13)

Since mono- and dinitrocarbazoles are not expl, they are not described here in detail. For addl info on props or methods of prepn the Refs given below should be consulted

*Refs:* 1)Beil **20**, 437, (166) & [285] 2)Beil **20**, 439 & [288] 3)Beil **20**, 440, (168) & [288] 4) Beil **20**, 440,441 & [289] 5)M.A.Il'inskii et al, ZhKhimProm **5**, 469-73(1928) & CA **22**, 3888-9 (1928) 6)N.Campbell & B.M.Barclay, JCS **1945**, 530 7)N.Campbell & B.M.Barclay, ChemRevs **40**, 359-80(1947) 8)G.N.Anderson & N.Campbell, JCS **1950**, 2904-5 9)W.A.Schroeder et al, IEC **43**, 941,943(1951) 10)P.A.S.Smith & B.B.Brown, JACS **73**, 2436-37(1951) 11)H.Leditschke, Chem-Ber **86**, 522-24(1953) & CA **49**, 8246(1955) 12) W.C.Sumpter & F.M.Miller, "Heterocyclic Compounds with Indole and Carbazole Systems", Interscience, NY (1954),pp 81-5 13) B.Stárková et al, ChemListy **51**, 536-8(1957) & CA **51**, 10541(1957) 14)A.V.Topchiev,"Nitration of Hydrocarbons and Other Organic Compounds", Pergamon Press, NY(1959),p 40

*Trinitronitrocarbazole,* $C_{12}H_6N_4O_6$, mw 300.20, N 18.54%; not found in Beil or in CA thru 1960

**Tetranitrocarbazoles**(TeNCbz), $C_{12}H_5N_5O_8$; mw 347.20, N 20.17%. The nitration of carbazole or N-acetylcarbazole with strong $HNO_3$ or by other means, produces a yel-colored expl product which corresponds to the above empirical formula. The product is now known to be a mixt which is difficult to separate into its isomeric components(See below)

The prepn of TeNCbz was first reported in 1880 by Graebe(Ref 2) who nitrated carbazole with 94% $HNO_3$. Similar procedures were followed by Escales(Ref 4) and Ziersch(Ref 5). However Ciamician & Silber(Ref 3) observed that four isomers TeNCbz's were formed when acetylcarbazole was treated with fuming $HNO_3$. In 1912 & 1913 Cassella & Co(Ref 6) obtd patents covering the manuf of polynitrocarbazoles by the process of dissolving carbazole in $H_2SO_4$ and treating the soln of sulfonic acids with strong nitrating agents. The crude product, thus prepd, contained principally 1,3,6,8-TeNCbz (Ref 7) and about 10% of the 1,2,6,8-TeNCbz isomer(Ref 15). The prepn & manuf of TeNCbz is described also by Raudnitz & H.Böhm(Ref 8), Amemiya et al, (Ref 16), Livingston(Ref 12), Baer(Ref 17), Pfaff(Ref 10) and others

The TeNCbz isomers listed in Beil and in some other Refs are as follows: *α-Tetranitrocarbazole,* lt-yel ndls, mp 285-86°(Escales) & 308°(dec)(Ciamican & Silber); *β-Tetranitrocarbazole,* lt-yel pltls(from glac AcOH), mp 273°(Escales) & a product mp above 320° (Ciamician & Silber); *γ- or 1,3,6,8-Tetranitrocarbazole,* lt yel pltlts(from nitrobenz), mp 285°(Ziersch and Borsche & Scholten) or golden yel ndls(from glacial AcOH), mp 289°(Raudnitz) or pale yel ndls(from glac AcOH), mp 295.6 -296°(Murphy et al); and *δ-Tetranitrocarbazole,* yel prisms(from glac AcOH), mp dec on heating ca 200°(Escales and Ciamician & Silber)

The structure of these isomers, except that of 1,3,6,8-TeNCbz, has not been definitely established(See "Separation of Isomers from Crude Product" discussed below)

Health hazards connected with the use of TeNCbz as an insecticide(Ref 11) and of other pesticides are discussed by Brieskorn(Ref 13) although Sax(Ref 19) reports that toxicity details are unknown

The expl props(Ref 20) of TeNCbz (principally the 1,3,6,8-isomers) have been detd as follows: *Brisance* by Sand Test, 41 gms sand crushed; *Explosion Temperature,* C°, 470 dec in 5 secs; *Impact Sensitivity,* 2kg wt, 18 inches using 14mg sample & PA Apparatus; *Heat of Combustion,* $Q_c^v$, 1310 kcal/mol(Ref 18); *Heat of Formation,* $Q_f^v$-6.9 kcal/mol(Ref 18); *100°C Heat Test,* % Loss 1st 48hrs 0.15, % Loss 2nd 48hrs 0.05, Explosion in 100hrs none; *Hygroscopicity* at 30°C & 90% RH 0.01%; *Sensitivity to Initiation* 0.20g LA & 0.25g Tetryl reqd for 0.4g sample in 200g Sand Bomb

*Uses:* According to Pfaff(Ref 10), 1,3,6, 8-TeNCbz(also called "Nitrosan") has been used as an insecticide against grape insects, replacing arsenic prepns previously used. It was proposed, during WWII in Germany, as a substitute for BkPdr in first fire compns for

illuminating flares. Due to its non-hygroscopic & non-corrosive props, TeNCbz was expected to completely replace BkPdr in igniter compositions. To avoid destruction(deterioration & thus became unserviceable) in storage of pyrotechnic devices contg Mg, it was proposed to also replace the BkPdr "intermediate" composition by the following mixt: TeNCbz 30, $KNO_3$ 40 & Al powd 30% (Ref 21)

In the USA, TeNCbz has been studied at PicArsn for use in ignition type powders (Ref 12 & 15) and for other components of ammunition(Ref PATR **1984** & **2180**)

**Tetranitrocarbazole(TeNCbz). Separation of Isomers from Crude Product.** Four isomers: $\alpha,\beta,\gamma$ and $\delta$ listed in Beil(Ref 1), were separated by Ciamician & Silber(Ref 3) and later by Escales(Ref 4), but their structure was not established

The separation of the isomers was conducted by Escales as follows: Crude TeNCbz (1 part)(prepd by nitration of carbazole with fuming $HNO_3$), was extracted in a Soxhlet for 8hrs using 8ps of glac AcOH. After extracting, the residue which was insol in acid was separated as a yel pdr which melted with decompn ca 274°(crude *α-TeNCnz).* The filtrate was allowed to stand until it deposited rust-brn crysts which began to melt ca 240° and decomp ca 260°(crude *β-TeNCbz).* The filtrate was evaported to ca ¼th vol and cooled. This produced a large deposit of red-brn, soft plates melting at 264-5° with decompn (crude *γ-TeNCbz).* The remaining mother liquor was slowly poured into ice-water to precipitate a lt yel, fine pdr, which decompd on heating to ca 200°, without melting (crude *δ-TeNCbz)*

On crystn of the crude *α*-compd from acet, lt yel crysts melting at 285-6° were obtained. When treated with KOH soln the product turned yel and the color intensified with heating

On treating the crude *β*-compd with glac AcOH, the bulk of product dissolved leaving as residue some *α*-compd. After removing the residue, the filtrate was allowed to stand for 24hrs to deposit a dk-brn amorphous mass with mp ca 273°(not sharp). Warming the *β*-compd with KOH soln produced a red coloration

On treating the crude *γ*-compd with glac AcOH, only part dissolved, leaving a yel-brn pdr, mp ca 275°. The same substance precipitated from AcOH soln after allowing it to stand for 12hrs. This material was claimed to be *1,3,6,8-TeNCbz* or *Nitrosan.* When treated with KOH soln, the product turned red immediately, the color intensifying on heating

The crude *δ*-compd could not be purified by crystn

No structure of these compds was established, except that of the 1,3,6,8-isomer

Borsche & Scholten(Ref 7) prepd TeNCbz,(by heating tetranitromethoxybiphenyl with alc ammonia) as red-brn, thin prisms, mp 285° and showed that it was mostly the 1,3,6, 8-isomer

Murphy et al(Ref 15) investigated at PicArsn crude TeNCbz prepd by sulfonation and subsequent nitration of carbazole. They separated (by repeated fractional crystns from acetone), three fractions varying in their solubilities in acet. The most sol of these fractions, obtained in small amt, contained ca 13% N(compared with the calcd value of 20.17% for TeNCbz). Based upon this analysis and the poor resolution obtained in the infrared spectra of this substance, it was belived to be a mixt of decompn and condensation products formed in the reaction, together with partially nitrated carbazole. Both the middle fraction(mp 253-4°, after recrystn from acet) and the least soluble(3rd),fraction(mp 295-6°, after rerystn from AcOH), had N contents close to the calcd value for TeNCbz, indicating that they were isomers

The least sol fraction was easily proved to be 1,3,6,8-(or symmetrical) TeNCbz, because it was identical with the sample prepd by heating 3,3',5,5'-tetranitro-2,2'-dimethoxy-biphenyl in a sealed tube. The structure of the middle portion was not so easy to determine. It was at first believed to be 2,3,6,8-isomer but investigation by the method of infrared absorption spectra showed it to be 1,2,6,8 -TeNCbz. No other isomers were obtained by Murphy et al

*Refs:* 1)Beil **20**, 441, (168) & [290] 2) C.Graebe & B.vonAdlerskron, Ann **202**, 26 (1880) 3)G.L.Ciamician & P.Silber, Gazz **12**, 277(1882) & JSCI **1**, 352(1882) 4)R.Escales, Ber **37**, 3596(1904) 5)P.Ziersch, Ber **42**, 3800(1909) 6)L.Cassella & Co, GerP 268173 (1912) & FrP 464538(1913) 7)W.Borsche & B.G.B.Scholten, Ber **50**, 596, 606 & 608(1917) 8)H.Raudnitz & H.Böhm, Ber **60** 741(1927) 9) Thorpe **2**(1938), 278 10)K.Pfaff, Reichsamt-Wirtschaftsausbau ChemBer **PB52021**, 1183-91 (1942) & CA **42**, 9044-45(1948) 11)K.Pfaff, USP 2375382(1945) & CA **40**, 426(1946) 12)

S.Livingston, PACLR 136330(1951) & PATR **2267**(1956) 13)C.H.Brieskorn, ZLebensm -Untersuch u -Forsch **93**, 292-98(1951) & CA **46**, 1203(1952) 14)Kirk & Othmer **7**(1951), 437 & **13**(1954), 330 15)D.B.Murphy et al, PAMR No **MR-22**(1952)(Conf) & JACS **75**, 4289-91(1953) 16)T.Amemiya et al, Coal Tar(Japan) **4**, 323-25 (1952) & CA **48**, 2034(1954) 17)M.Baer, PATR **1948**(1953) 18)P.Tavernier & M.Lamouroux, MP **30**, 354(1957) 19)Sax(1957), 1170 20)PATR **1740**, Rev 1(1958), 292-95 21)PATR **2510**(1958), 197 22)US Spec MIL-T -13723A(Tetranitrocarbazole for Ordnance use)

**Tetranitrocarbazole(TeNCbz) Analytical Procedures.** TeNCbz used as an ingredient of explosive,igniter & pyrotechnic compns is usually a crude product purified only to remove the acidity, mono- dinitrocarbazoles and decompn products formed during nitration. This TeNCbz consists principally of 1,3,6,8-TeNCbz and about 10% of the 1,2,6,8-isomer. When treated with KOH soln, both isomers turn red and the color is intensified on heating(Refs 1 & 2)

Compn of TeNCbz prepd at PicArsn by Livingston(Ref 3) was established by detg total nitrogen content(using micro-Kjeldahl app), nitro-nitrogen content(by titanous chloride method) and carbon-hydrogen content(by micro -combustion method)

For detn of purity of TeNCbz, Kaye(Ref 4) developed at PicArsn a method of titration, using dimethyl formamide as a medium and a soln Na methoxide as the titrant. As the end point could not be detd visually(using azo violet as indicator) due to the darkening of the TeNCbz sample in the vicinity of its end point, a potentiometric procedure was used, employing antimony and calomel electrodes. It was found that production grade TeNCbz gave purity values which were consistently slightly in excess of 100%(such as 100.15%). This anomaly may be due to traces of acidic impurities retained in the compd after its synthesis and purification. These acidic compds neutralize part of the Na methoxide titrant, thus giving a higher reading in titration. Purity of production grade material after its purification by recrtsg twice ftom acetone was ca 99.9%

Requiremants of US Armed Forces for TeNCbz used for military purposes are covered by Specification MIL-T-13723A, superseding PA-PD-639. These requirements are:

a)*Primary Material.* The carbazole used in the manuf of TeNCbz shall comply with Spec MIL-C -13613(Ord)(See under Carbazole, Analytical Procedures)

b)*Moisture in TeNCbz*–0.20%, max[when detd by heating a 5g at 105± 5° to const wt(ca 1.5hrs), as specified in 4.4]

b)*Nitro- nitrogen Content*–15.50%, min(when detd by titanous chloride proced, as specified in 4.5.2)

c)*Surface Alkalinity*–0.05% as $NH_3$, max(when detd by titrating with 0.05NHCl a 200ml portion of distd w used for rinsing the surface of 10g crystalline TeNCbz, as specified in 4.6)

d)*Surface Acidity*–0.20% as $H_2SO_4$, max(when detd as in above process, but using for titration 0.05N soln of NaOH, as specified in 4.7)

e)*Total Acidity*–0.20% as $H_2SO_4$, max(when detd by titrating with 0.01N NaOH soln the liquid prepd by heating a 5g sample in 400ml acet and adding 400ml distd w, as specified in 4.8)

f)*Total Alkalinity*–0.05% as $NH_3$, max(when detd as in above proced, but using for titration 0.01N HCl soln, as specified in 4.9)

g)*Melting Point*–285 to 300° (when detd as specified in 4.10)

*Note:* The app and proced are similar to those given in Vol 1,pp A612–R & A613–L

h)*Acetone Insoluble Material*–0.15%, max(when detd by weighing a residue remaining after treating a 5g sample with two 200ml portions of hot acet, as specified in 4.11)

i)Granulation–a min of 100% shall pass thru a No 100 sieve, when detd as specified in 4.12

*Note:* Info about sieves is given in Table 1,p A674, Vol 1 of this Encyclopedia

*Refs:* 1)R.Escales, Ber **37**, 3597(1904) 2)W.Fischer, ZAnalChem **131**, 192-8(1950) & CA **45**, 803(1951) 3)S.Livingston, PicArsnChemLabRept 136330 (1951) 4)S.M.Kaye, PATR **1937**(1953)

**Carbazotine**(Fr). Same as Carboazotine

**Carbazotique, Acide**(Fr). Picric Acid

**Carbene.** 1)Same as *Cuprene*, $(C_{11-15}H_{10})_x$, a yel-brn polymerization product made by heating acetylene in the presence of Cu(Ref 1) 2)A positive or negative ion involving two- valent carbon and paired electrons as in $H_2C$:, $R_2C$: or $R_2C^{++}$. These ions are different from methylene free radicals in that the latter have unpaired electrons. Carbenes have only transitory existence and are difficult or impossible to collect as such, but

have important functions as intermediates in chem reactions (Ref 3). See also Ref 2 3) Constituent of bitumen, insol in $CCl_4$ or chlf but sol in $CS_2$(Refs 1 & 4). Carbenes have been used as ingredients of some coml expls. See also *bitumens* under Asphalt, Vol 1,p A496R
*Refs:* 1)Hackh's(1944), 166 & 241 2)P.S.Skell & R.C.Woodworth, JACS **78**, 4496-7(1956) & CA **50**, 16656(1956) (Structure of carbene, $CH_2$) 3)Cond-Chem Dict(1961), 215 4)Merriam-Webster's (1961), 335

**Carbethoxy.** See Carboethoxy

**Carbides, Carbonides or Carburets.** Binary compods of carbon and a metal. Some carbides dec readily in w to give acetylene ($Li_4C$,$K_4C$,$CaC_2$,$SrC_2$ or $BaC_2$); others form methane($Al_2C$ or $B_2C$), or hydrogen & methane($MgC_2$,$Mn_3C$ or $Cr_3C$), or a mixt of acetylene, hydrogen & methane (rare earth carbides); while those of the rare metals ($ThC_2$ or $U_2C_3$) form solid, liq or gaseous hydrocarbons. Carbides such as SiC or $Ti_xC_y$ are extremely stable(Ref 1)
See Acetylides and Carbides, Vol 1, p A69ff and Ref 2
*Refs:* 1)Hackh's(1944), 166 2)M.Déribéré, JFourElec **45**, 344-5(1936) & CA **31**, 865(1937)(Explosions in iron carbide drums)

**Carbine**(Karabiner in Ger; Carabine in Fr; Karabin in Rus; Carabina in Ital and Carabina in Span). A short, light weight rifle formerly used by cavalry and mounted infantry, but in recent years also used by other troops. The term "carbine" is probably derived from "carabineros", Spanish mounted troops which were equipped, beginning the middle of 16th century, with a short light wt firearm which could be fired directly from a horse. This weapon was called *petronel* or *poitrinale* (See under Bullets, Historical and also Refs 3 & 4)

Carbines used by the US Armed Forces during WWII were either semiautomatic or automatic. For their description, see Refs 3 & 6

The story of how Amer industry helped to develop modern carbines is told by Carlen (Ref 2)
*Refs:* 1)Anon, "Small Arms Matériel", TM **9-2200**(1949), 15 2)Col L.A.Carlen, Ordn **36**, 151-3(1951) 3)W.H.B.Smith, "The NRA Book of Small Arms" The Stackpole Co, Harrisburg, Pa, v2(1952), 30 & 378 4) W.Y.Carman, "A History of Firearms", StMartin's Press, NY(1955), 125-30 5) Glossary of Ord(1959)55-6 6)W.H.B.Smith, "Small Arms of the World", The Stackpole Co, Harrisburg,Pa(1960), 87-92 & 628-31

**Carbite.** A dynamite,proposed by Dautriche (Ref 1) and approved in 1907 by the Commission des Substances Explosives,consisted of: NG 25, $KNO_3$ 34, wheat flour or starch 38.5, $Ba(NO_3)_2$ 1, powd bark 1 & $Na_2CO_3$ 0.5%
*Refs:* 1)M.Dautriche, MP **14**, 177(1906-7) & CA **3**, 2053(1909) 2)Marshall, Dict(1920), 18 3)CondChemDict(1942), 288 (not found in later editions)

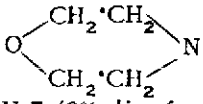
**"Carbitol".** A trademark of the Union Carbide Corp for mono- and dialkyl ethers of diethylene glycol & their derivs
*Refs:* 1)Hackh's(1944), 166 2)Sax(1957), 435 3)CondChemDict(1961), 216

**"Carbitol" Solvent or Diethylene Glycol Monoethyl Ether** (called Diäthylenglykol -monoäthyläther in Ger), $C_2H_5{\cdot}O{\cdot}CH_2{\cdot}CH_2{\cdot}O{\cdot}CH_2{\cdot}CH_2{\cdot}OH$ ; mw 134.17; col hygr liq, having a mild pleasant odor, bp 195-202°, flash p 205°F(OC), d 1.027 at 20°, vap d 4.62, $n_D$ 1.425 at 25°; other props & methods of prepn are given in the Refs. It is used as a solv for dyes, NC, resins & other materials
*Refs:* 1)Beil **1**, [520] & {2096} 2)Hackh's (1944), 166 3)Sax (1957), 435 4)CondChem Dict (1961), 376

**Carboazotine or Cahuecit.** One of the early safety blasting expls invented in the 1870's by R.Cahuc. Its compn in *England* was $KNO_3$ 64, sulfur 12, lampblack or soot 7 & bark or wood pulp 17%; in *France* (called Poudre de mine de Soulages ou de Sûreté) $NaNO_3$ 50 to 60, sulfur 13 to 16, spent tan bark 14 to 16, soot 9 to 18 & Fe sulfate 4 to 5%; and in *Germany* (called Cahüsit) $KNO_3$ or $NaNO_3$ 70, sulfur 12, lampblack or soot 8 & bark or woodpulp 10%. The ingredients were incorporated with a considerable amt of water, which afterwards was evaporated. This expl was considered comparatively mild

*Refs:* 1)Cundill (1889); Fr translation MP **6**, 101-2(1893) 2)Gody (1907), 171 3)Marshall **1**(1917), 89 and "Dictionary of Explosives" (1920), 16-7 4)Ullmann, vol 4(1929), 780 5)Pepin Lehalleur(1935), 287 6)Thorpe (1940), 463 6)CondChemDict (1942), 288(not found in later editions) 7)PATR **2510** (1958), p Ger 23

**N(or 4)-Carbobutoxy-morpholine**(called Butyluréthane de la morpholine or Morpholine uréthane butylique in Fr),



; mw 187.33, N 7.48%; liq, fr p -4°, bp 252-2.5°; was prepd by the action of butylchloroformate on an aq soln of morpholine(Ref 2). It was tried in France as a possible substitute for centralite in solventless, smokeless proplnts (poudres SD)(Ref 3). The props of proplnts prepd with this compd resembled those contg N(or 4)-carboethoxy-morpholine (qv)
*Refs:* 1)Beil—not found 2)L.Médard,BullFr [5] **3**, 1343(1936) & CA **30**, 7577-8(1936) 3)R.Dalbert & H.Ficheroulle, MP **30**, 283-300(1948)

**Carbodynamites.** Explosives patented in 1886 by Borland & Reid of GtBr. These compns differed from ordinary dynamite in that NG was absorbed in cork charcoal instead of kieselguhr. Two compns consisted of the following: **No 1** NG 90 & cork charcoal 10%; **No 2** NG 71.4, $KNO_3$ 20 & cork charcoal 8.6%. As stabilizers Amm or Na carbonate up to 1.5% of total wt of expl was sometimes added. There existed also a variety of carbodynamites contg up to 20% of water; these expls were comparatively safe to handle
*Refs:* 1)Daniel (1902), 108-9 2)Barnett (1919), 97 3)Marshall, Dict(1920), 18 3) CondChemDict(1942), 288(not found in later editions)

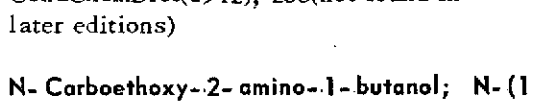
**N-Carboethoxy-2-amino-1-butanol; N-(1-Butanol)-urethane; N-(1-Hydroxybutane)-urethane or 1-Hydroxy-2-urethane-butane,** $CH_3{\cdot}CH_2{\cdot}\underset{\displaystyle NH{\cdot}COOC_2H_5}{\underset{|}{CH}}{\cdot}CH_2{\cdot}OH$, and its nitrated deriv, $CH_3{\cdot}CH_2{\cdot}\underset{\displaystyle N(NO_2){\cdot}COOC_2H_5}{\underset{|}{CH}}{\cdot}CH_2{\cdot}ONO_2$, serve as intermediate compds in the prepn of *2-Nitramino-1-butanol Nitrate* listed under 2-Amino-1-butanol, Vol **1**,p A192-R

**N-Carboethoxy-1-amino-2-ethanol; N-(2-Ethanol)-urethane; N-(2-Hydroxyethane)-urethane or 2-Hydroxy-2-urethane-ethane,** $HO{\cdot}CH_2{\cdot}CH_2{\cdot}NH(COOC_2H_5)$, and its nitrated deriv, $O_2NO{\cdot}CH_2{\cdot}CH_2N(NO_2)(COOC_2H_5)$, serve as intermediate compds in the prepn of *NENA* described under Aminoethanol and Derivatives, Vol **1**,p A201-L

**N-Carboethoxy-2-amino-2-methyl-1-propanol; N-Carboethoxy-2-amino-2-methyl-1-hydroxypropane or 1-Hydroxy-2,2-dimethyl-2-urethane-ethane,** $H_3C-\underset{\displaystyle CH_3}{\underset{|}{\underset{\displaystyle NH{\cdot}COOC_2H_5}{\underset{|}{C}}}}-CH_2OH$, and its nitrated deriv, $H_3C-\underset{\displaystyle CH_3}{\underset{|}{\underset{\displaystyle N(NO_2){\cdot}COOC_2H_5}{\underset{|}{C}}}}-CH_2(ONO_2)$, serve as intermediate compds in the prepn of *2-Nitramino-2-methyl-1-propanol Nitrate* described under Aminomethylpropanols and Derivatives, Vol **1**,p A233-R

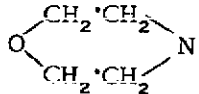
**N-Carboethoxy-1-amino-2-propanol; N-(2-Propanol)-urethane; N-(2-Hydroxypropane)-urethane or 2-Hydroxy-(1-urethane)-propane,** $\underset{\displaystyle NHCOOC_2H_5}{\underset{|}{CH_2{\cdot}CH(OH)CH_3}}$, and its nitrated deriv, $\underset{\displaystyle N(NO_2)COOC_2H_5}{\underset{|}{CH_2{\cdot}CH(ONO_2)CH_3}}$, serve as intermediate compds in the prepn of *Nitraminopropanol Nitrate* described under Aminopropanols and Derivatives, Vol **1**,p A253-L

**N-Carboethoxy-furfurine or Urethane-furfurine**(called Ethyluréthane de la furfurine or Furfurine uréthane éthylique in Fr and Furfurin-N-carbonsäureäthylester in Ger),



; mw 340.32, N 8.23%; prisms (from alc), mp 120-4°; insol in eth; diffc sol in w; was prepd by reacting furfurine with ethyl chloroformate in abs eth (Refs 1 & 2). It was tried in France as a possible substitute for centralite in solventless, smokeless proplnts (poudres SD), but proplnts prepd with it were unsatisfactory (Ref 3)
*Refs:* 1)Beil **27**, 764 2)R.Bahrmann,

JPraktChem **27**, 318(1883) 3)R.Dalbert & H.Ficheroulle, MP **30**, 283–300(1948)

**N(or 4)-Carboethoxy-morpholine or Urethane-morpholine**[called Ethyluréthane de la morpholine or Morpholine uréthane éthylique in Fr and Morpholin-carbonsäure-(4)-äthylester in Ger],  ; mw 159.18, N 8.80%; oil, fr p 2.5°, bp 220–1° at 746mm (Refs 1 & 2), bp 223° at 764mm (Ref 3) & bp 251° (Ref 4); was prepd by the action of ethylchloroformate on an aq soln of morpholine (Refs 1,2 & 3). It was tried in France as a possible substitute for centralite in solventless, smokeless proplnts (Ref 4). A compn (contg NC, NG, carboethoxymorpholine & centralite) was easy to roll or extrude but the resulting proplnt was more brittle than when prepd with centralite alone. The stability of proplnts made with carboethoxy-morpholine was fairly satisfactory even at temps up to 90°
*Refs:* 1)Beil **27**, 7 2)L.Knorr, Ann **301**, 7(1898) 3)L.Médard, BullFr[5] **3**, 1343(1936) & CA **30**, 7577-8(1936) 4)R.Dalbert & H.Ficheroulle, MP **30**, 283-300(1948)

**Carboethoxynitramine.** See Nitrocarbamic Acid Ethyl Ester under Carbamic Acid and Derivatives

**Carboethoxynitrosamine.** See Nitrocarbamic Acid Ethyl Ester under Carbamic Acid and Derivatives

**[I(or N')-Carboethoxyphenyl-III(or N)-carbanilino]-triazene or [I(or N')-Carboethoxyphenyl-III(or N)-phenylcarbamyl]-triazene** {called 1(oder 3)-[4-Carbäthoxy-phenyl]-triazen-(1)-carbonsäure-(3 oder 1)-anilid or N'-[4-Carbäthoxy-benzoldiazo]-N-phenyl-harnstoff, in Ger}, $C_6H_5{\cdot}NH{\cdot}CO{\cdot}NH{\cdot}N{:}NC_6H_4{\cdot}COO{\cdot}C_2H_5$ ; mw 312.32, N 17.94%; col pltlts (from alc), mp 135° (dec); readily sol in chlf, eth or hot alc; insol in w; was prepd from the reaction of 4-triazeno-benzoic acid ethyl ester and phenylisocyanate in eth (Refs 1 & 2)
*Refs:* 1)Beil **16**, (411) 2)O.Dimroth & K.Pfister, Ber **43**, 2764(1910) & JCS **98** I, 904–5(1910)

**4-Carboethoxy-phenyltriazene**(called 4-Carbäthoxy-phenyltriazen or 4-Triazeno-benzoesäureäthylester in Ger), $H_2N_3C_6H_4{\cdot}COOC_2H_5$; mw 193.20, N 21.75%; granules or ndls (from eth + gasoline), mp 68° (dec); was prepd by reduction of 4-azidobenzoic acid ethyl ester by $SnCl_2$ soln in eth. This compd dec on long storage even below RT, at higher temps it dec explosively; dec in alc or dil acids; an ethereal soln with formaldehyde condenses to form a compd decomg at 48°; it combines with benzaldehyde, but the compd is too unstable to isolate(Refs 1 & 2)

It forms salts, some of which are expl:
*Copper salt*, $CuC_9H_{10}N_3O_2$ , golden-yel lfts(from chlf), dec at 130° and expl over a flame; *Tin salt*, expl on heating
*Refs:* 1)Beil **16** (410) 2)O.Dimroth & K.Pfister, Ber **43**, 2763-64(1910); JCS **98** I, 905-6(1910) & CA **5**, 486(1911)

**Carbogelatin.** A Brit expl consisting of NG (gelatinized with NC) 38.5, K or Na nitrate 49.5, woodmeal with charcoal 10.5 & $MgCO_3$ 1.5%
*Ref:* Daniel(1902), 109

**Carbohydrates.** A class of compds of C,H & O in which H & O are in the same proprotion as in $H_2O$. Also org compds which are synthesized by plants. A more rigorous definition is that carbohydrates are aldehyde alcohols, ketone alcohols or compds that on hydrolysis produce aldehyde or ketone alcohols. Examples of carbohydrates are the cryst, sol, sweet, low molecular wt sugars; and the amor, tasteless, relatively insol high molecular wt starches & cellulose. Specific examples are sucrose, $C_{12}H_{22}O_{11}$, and starch, $(C_6H_{10}O_5)_X$(Refs 2 & 12)

Some reactions relating to carbohydrates were studied by Ashford et al(Ref 3). The nitration of carbohydrates & their stability have been studied by many investigators, such as Ashford et al (Ref 4), Wolform(Ref 11) and many others. See also Evans (Ref 1), Dorée(Ref 5), K & O(Ref 6), Vollmert(Ref 7), Orr(Ref 8) Wolfrom & Tipson(Ref 9) and Honeyman (Ref 10)
*Refs:* 1)W.L.Evans, ChemRevs **31**, 537-60(1941)(Some aspects of carbohydrate chemistry) 2)Hackh's(1944), 217 3) W.R.Ashford et al, CanJRes **24B**, 238-45 (1946)(Stabilizing action of ethanol on starch nitrate); Ibid, **24B**, 246-53(1946)(Props of fractionated nitrates of cornstarch) 4)

W.R.Ashford et al, CanJRes **25B**, 151-54 (1947)(Effect of hot alkali solns on the nitrates of starch, amylose & amylopectin); Ibid, **25B**, 155-58(1947)(Stability of maltose & cellobiose octanitrates) 5)C.Dorée, "The Methods of Cellulose Chemistry", Chapman & Hall, London(1947), 543 pp 6)Kirk & Othmer, **3**(1949), 342ff 7)B.Vollmert, MakrChem **6**, 78-84(1951) & CA **45**, 9487(1951) 8)E.Ott, "Cellulose and Cellulose Derivatives", Vol **5** of High Polymer Series, Interscience, NY, Three Parts(1954-55) 9)M.L.Wolfrom & R.S.Tipson, "Advances in Carbohydrate Chemistry", Academic Press, NY, Vol II(1956) 10) J.Honeyman, Edit, "Recent Advances in the Chemistry of Cellulose and Starch", Interscience, NY(1959) 11)M.L.Wolfrom, "Study of Nitrated Carbohydrates", Ohio State Univ Quart Prog Repts No 1, 2 & 3(Feb 1959 - Oct 1959)(Proj No 2317, Contract No DA-33 -019ORD-2923 12)CondChemDict(1961), 217

**Carbohydrazide; sym or N,N'-Diaminourea** (called Carbohydrazid; Kohlensäuredihydrazid or N,N'-Diamino-harnstoff in Ger), $CO(NH{\cdot}NH_2)_2$; mw 90.09, N 62.20%; col ndls (from dil alc), mp 152-54°; d 1.616 at 20°; insol in eth, benz or chlf; other props & various methods of prepn are given in Beil(Ref 1)(See also Ref 2)

Carbohydrazide is not an expl, but in the presence of nitrous acid is converted into the highly expl *Carbonyl Azide*, $CO(N_3)_2$(See Vol **1**, p A528-L)

It is incompatible with NC as the film prepd from a mixt of NC & carbohydrazide gave 11cc in 16hrs in the 90° Vac Stab Test, and exploded after 8hrs heating in the 120° Heat Test(Ref 3)

*Refs:* 1)Beil **3**, 121, (57), [96] & {231} Univ of Illinois, Urbana, Ill, 2)L.F.Audrieth & E.B.Mohr, Progress Rept IV, Contract No W-11 -022-ORD-11329(1949) 3)J.P.Picard & W.P.Morton, PicArsn data(May 1955)

**Carbohydrazide-N-carbamoyl**(called 1-Carbamoyl-carbohydrazid or Hydrazin-N.N'-dicarbosäure-amid-hydrazid in Ger), $H_2N{\cdot}NH{\cdot}CO{\cdot}NH{\cdot}NH{\cdot}CO{\cdot}NH_2$; mw 133.12, N 52.61%; crysts(from boiling w), mp 228°(dec); sol in dil mineral acids; sol in KOH soln with decompn; insol in w, alc or other org solvs; when heated at 226° it cyclizes, in part, to form urazine. Other props & methods of prepn are given in Beil and in Ref 2

*Refs:* 1)Beil **3**, 121, [96] & {232} 2)L.F.Audrieth et al, Inorg Synth **4**(1953), 36

**Carbohydrazide-N-carboxyamide**, $C_2H_7N_5O_2$. See S.Helf, PATR **1752**(1949)(Conf)

**Carbohydrazide-N,N-dicarbamoyl**(called 1,5-Dicarbamoyl-carbohydrazid or Carbonyl-bis-semicarbazid in Ger), $CO(NH{\cdot}NH{\cdot}CO{\cdot}NH_2)_2$; mw 176.14, N 47.72%; col crysts (from w), mp 225-32°(dec); sol in hot w, diffc sol in cold w; insol dil acids, alc, eth or other org solvs; when heated with w in a test tube at 150°, it yields carbohydrazide & 4-aminourazole. Other props & methods of prepn are given in Beil and in Ref 2

*Refs:* 1)Beil **3**,122, [97] & {232} 2) L.F.Audrieth & P.H.Mohr, Inorg Synth **4**(1953), 38

**Carbohydrazide-N,N'-dicarboxyamide**, $C_3H_8N_6O_3$. See S.Helf, PATR **1752**(1949)(Conf)

**Carbomethoxynitramine.** See Nitrocarbamic Acid Methyl Ester under Carbamic Acid and Derivatives

**Carbomethoxynitrosamine.** See Nitrosocarbamic Acid Methyl Ester under Carbamic Acid and Derivatives

**CARBON**(Carbone in Fr, Carbon or Kohlenstoff in Ger, Carbonio in Ital, Carbono in Port, Ugol' or Karbon in Rus & Carbón in Sp), C, at wt 12.01; blk crysts or powd, mp 3652°-3697° (sublimes), bp 4200° (approx); d 1.8-2.1 (amor), 2.25 (graphite), 3.51 (diamond), vap press 1mm at 3586°; in the form of graphite it can cause dust irritation to the eyes, in the form of soot it can cause conjunctivitis and other inflammation of the eyelids & cornea (Ref 45)

Carbon occurs free in nature and has been known since ancient times. It is the basic element around which all organic life revolves. It exists in two cryst forms: *diamond & graphite* and in various("amorphous") forms, such as *carbonblacks* (acetylyne black, lampblack, etc) and *charcoal*. Soot & coke are impure amorphous carbon

Diamond is one of the hardest known substances and because of its props is used to cut glass & minerals, in drilling tools and as bearings in watches & other precision instruments. Graphite is used in pencils, in refractory crucibles and in electrotyping. The

use of graphite in expls & proplnts is described below. "Amorphous" carbon or carbon blacks, of which there are several kinds, are made by burning org substances in an insufficient supply of air. This important group of industrial carbons are used in the rubber tire industry, in plastic compounding, as thermal insulators, and as black pigment in ink & paint industries. It is an essential component of some metals such as cast iron & steel. A special form of carbon called "Active" or "Activated", prepd by carbonization of carbon-containing materials such as wood, sawdust, peat, lignite etc, is used for its absorptive props in removing odors, tastes, colors etc from liquids & gases

*Explosibility of Carbon Dust & Its Use in Explosives.* Carbon black, presumably produced by incomplete combustion of natural gas, was easily ignited, and it propagated a flame readily when the testing gallery at the US Bur Mines Experiment Station was loaded with a concn of 12g dust $1ft^3$ (Ref 2). Researches on the explosibility of C dust in relation to initial ignition & conditions of dispersion are abstracted by Langhans (Ref 28). Sax (Ref 45) reports that activated C may spontaneously ignite on heating and explodes when its dust is exposed to flame. Elliott & Brown (Ref 13) investigated the expln hazards of mixts of perchloric acid & carbon, carbonaceous material and other org materials. The expln of C with liq air to give CO (Ref 6), and other processes or expln hazards involving C are described in the literature. See Refs given below, eg Reg 51

Capt Monni (Ref 1) reported in 1906 that the addn of C to one of the "ballistites" lowered the temp of combustion, increased the vol of gases and decreased the chamber press per kg of propellant; and carbon decreased the propellants' rate of burning. Gun erosion caused by such proplnts was less than that produced by straight ballistite. The C contg proplnts were claimed to be easy to make, resistant to variations in temp & humidity, constant in ballistic action and they did not leave any residue in guns. The chemical factors affecting proplnt ignition, in addn to the presence of free O & C, are discussed in a recent article by Cook (Ref 40). Also the factors influencing the incendivity of permissible expls (AN+ carbonaceous materials) are reported by Hanna et al (Ref 53). Pring (Ref 21) found that the incorporation of small amts of C black in NGu proplnts assisted in ignition & improved their ballistic regularity. Streijffert (Ref 18) prepd expls by treating activated carbon with a liq such as NG or TeNMe, removing the surplus liq, treating the C with $HNO_3$ and neutralizing the acid with $NH_3$. The resulting mixt contd the $NH_4$ salt dispersed in the pores of C. The activated C used for solv recovery during WWII was also used in some US smokeless proplnts(Ref 11)

One of Hercules' Bullseye Propellants (qv) manufd during WWII contd some carbon black; the Hercules E J Propellant, called "Pigseye Powder", contd $KClO_4$ 56, NC 21, NG 13, Et cent 1.0 & carbon 9% (Ref 55). Carbon has been used in Ammonals (See Vol 1, pp A289, A290 & A299-L) in Black Powder (qv) and in a large number of other expl compns, such as Blasting Explosives, including Liquid Air & Liquid Oxygen Explosives (Oxyliquits). DeMent (Ref 54) used C in smoke compns

Coating smokeless proplnts with graphite usually achieve the following purposes: a)aids in removal of static electricity b)acts as burning deterrant c)acts as a lubricant and d)prevents caking or cohesion of the proplnt grains

Crawford (Ref 17) found that unstable burning in double-base proplnts can be overcome by incorporating in the powder opaque C black or, as Hickman (Ref 24) found, lampblack for preventing self-ignition by radiation. See also Cannonite

Some expl compns, contg C and examined at PicArsn included: *Illuminating Composition,* $Sr(NO_3)_2$ 54, Mg 33, PVC 10, C 3 & Ca stearate 1%; *Squib,* NC, (lacquer) 51, $KClO_3$ 44 & C 5%; *Flare,* Mg 44, $NaClO_4$ 35, $Na_2O_2$ 4, phenolformaldehyde resin 15 & graphite 2%; *Flare First Fire,* $KNO_3$ 64, C 17, S 14, & $Sb_2S_3$ 5%; *Relay Charge,* $KNO_3$ 64, C 14, S 16 & Al 6%; and a *Blasting Charge,* $KClO_3$ 46, S 6 & binder(rosin) 42%

See also Charcoal, Coal & other carbonaceous materials

*Refs:* 1)Capt (?) Monni, SS **1**, 305-8(1906) & CA **2**, 2993(1908) 2)Anon, ChemEngrg **27**, 123-24(1919) & CA **13**, 2130(1919) 3)Mellor **5** (1924), 710ff 4)A.Godel, Chim & Ind **29**, 3T -17 T(1933)(Activated carbon & its ind applications) 5)Thorpe **1**(1937), 140 & **2** (1938), 308-19 6)L'Air Liquide, FrP 861602 (1941) & CA **42**, 6500(1948) 7)Hackh's (1944), 167 8)T.D.Johnson, Jr & R.G.Woodbridge, Jr, USP 2342585(1944) & CA **38**, 4806(1944) (Purifying graphite after contamination by use in

glazing smokeless proplnts) 9)C.L.Mantell, "Industrial Carbon", Van Nostrand, NY(1946) 10)H.L.Riley, Quart Revs **1**, No 1, 59-72(1947) (A review on amorphous carbon & graphite) 11) Anon, Chem Engrg **54**, 98-99(Jan 1947) 12) Kirk & Othmer **2**(1948), 881; **3**(1949), 34ff & First Supplement (1957), 130–44 13)M.A.Elliott & F.W.Brown, US Bur Mines Rept Invest **4169** (1948), 17pp & CA **42**, 2431-32(1948) 14) W.M.Gaylord, Chem Engrg **55**, No 3, 225(1948) (Carbon & graphite) 15)B.L.Crawford, USP 2440327(1948) & CA **42**, 5230(1948) 16) J.Basiak & T.Niewiadomski, PrzChem **4**, 304–7 (1948)(Reviewof methods of producing carbon blacks, their props & uses) 17)B.L.Crawford, USP 2440327(1948) & CA **42**, 5230(1948) 18) P.W.Streijffert, USP 2485889(1949) & CA **44**, 2246(1950) 19)Partington (1950), 593ff 20) J.W.Hassler, "Active Carbon", ChemPub Co, NY (1951), 390pp 21)J.N.Pring, USP 2557463 (1951) & CA **45**, 9863(1951) 22)Anon, Chem Engrg **58**, 176-79(July 1951)(Carbon black) 23) E.Berl, USP 2567468(1951) & CA **46**, 1236 (1952)(Prepn of activated carbon) 24) C.N.Hickman, USP 2574479(1951) & CA **46**, 1259(1952) 24a)N.A.Pirozhkov, "Proizvodstvo Sazhi" (Production of Soot"), Gosudarst Nauch - Tekh Izdatel'stvo Legkoi Prom, Moscow(1951), 118pp 25)C.A.Stokes & H.Friedenstein, Northeastern Wood Utilization Council Bull, No **37**, 7-19(1952) & CA **46**, 4200(1952)(Props of comi charcoals in relation to industrial use) 26) J.W.Hassler, Northeastern Wood Utilization Council Bull, No **37**, 93-101(1952) & CA **46**, 4200(1952)(Review of methods for producing active carbon & of its industrial applications) 27)Anon, Chem Engrg **59**, No 3, 206-9(1952) & CA **46**, 4200(1952)(Carbon recovery from black ash) 28)Dr (?).Langhans,SS **1952**, 213-14 29) R.H.Savage, USP 2601953(1952) & CA **47**, 850(1953)(Graphite carbon) 30)A.E.Fross, USP 2619410(1952) & CA **47**, 850(1953)(Carbon black produced by expl conversion of methane - oxygen mixts) 31)ChemischeWerkeHüls, BritP 685160(1952) & CA **47**, 5100(1953) (Carbonization of fuels) 32)Van Nostrand-ChemDict(1953), 128 32a)V.P.Zuev & V.V.Mikhailov, "Proizvodstvo Sazhi" (Production of Soot"), Gosudarst Nauch-Tekh Izdatel'stvoKhimLit, Moscow(1953), 198pp 33)H.L.Ammann, USP 2658821(1953) & CA **48**, 1658(1954)(Apparatus for producing carbon black by expln process) 34)G.W.Govier et al, Can-Chem Processing **38**, No 5, 67-70(1954)(Carbon black from natural gas; a tech & economic discussion) 35)Metallgesellschaft A-G, BritP 704810(1954) & CA **48**, 9660(1954)(Active carbons) 36)J.H.Schroeder, JARS **23**, 25-7 (1953) & CA **48**, 6126(1954)(Performance of stoichiometric carbon-oxygen propellent system) 37)A.Humann, "Der Graphit Eigenschaften und Verwendungsmöglichkeiten in Industrie und Kraftfahrwesen", Verlag Tech, Berlin(1953) 38)L.J.Venuto, PaintManuf **24**, 197-202 & 227-34(1954) & CA **48**, 11078(1954) (Carbon blacks for protective coatings; manuf & general props and selection of materials) 39) M.Steinschlaeger,USP 2694621(1954)(Carbon black) 40)M.A.Cook, AIChEJournal, **1**, 391-400 (1955) & CA **50**, 1316-18(1956) 41) Deutsche Gold- u Silber-Scheideanstalt, vorm Roessler, BritP 738068(1955) & CA **50**, 9723 (1956)(Improved carbon black manuf) 42)Gmelin; Syst Nr **59**(1955) & (1959), 64ff 43)J.Q.Wood, USP 2735828(1956) & CA **50**, 9724(1956) (Recovery of carbon) 44)H.A.Braendle, USP 2735753(1956) & CA **50**, 9724(1956)(Improved carbon black manuf) 45)Sax(1957), 245, 436 46)F.C.Stehling et al, "Sixth Symposium on Combustion", Reinhold, NY (1957), 547–54 (Carbon formation from acetylene) 46a)Kirk & Othmer, First Suppl Volume(1957), 130-43 (Carbon black) 47)Anon, "Industrial Carbon and Graphite", SocChemInd, London(1958)(Papers read at the conference held in London 24 to 26 Sept 1957 with discussion that followed) 48) I.Asimov, "The World of Carbon", Abelard - Schumann, NY(1958) 49)ASTM Standards Including Tentatives Part 9 Plastics, Electrical Insulation, Rubber, Carbon Black", Am Soc Testing Materials, Philadelphia(1958); Supplement (1959) 50)Anon, "The Industrial Graphite Engineering Handbook", Natl Carbon Co, NY(1959) 51)A.K.Galwey & P.W.M.Jacobs, TrFaradSoc **56**, 581-90(1960) & CA **54**, 18045 (1960) [Below 240° various mixts of $NH_4ClO_4$ & C (sugar charcoal) undergo isothermal decompn; above 260° the reaction accelerates rapidly & results in a mild expln] 52)R.M.Krupka & D.E.Taylor, Corrosion **16**, 385t-89t(1960) & CA **54**, 19384(1960)(Behavior of graphite in rockets on reëntry) 53)N.E.Hanna et al, US Bur Mines RI **5867**(1961) 54)J DeMent, USP 2995526(1961),pp 25-7 55)G.D.Clift, Private communication (1962) 56)USSpec MIL - A-3850(Acetylene Black); MIL-C-20613 (Activated carbon, granular); MIL-C-506A (1) (Activated carbon, powered); and JAN-C-306

(1)(Carbon black, dry for use in expls)
*Addnl Ref:* L.Pauling et al, OSRD Rept **3783** (1944)(Ballistites of approx compn NC 52, NG 43, K nitrate 1.5, DEtPh 3.0 & DPhA 0.5% exhibited better thermal stability with added carbon black, ca 0.1%, than with Nigrosine dye. These substances serve as opacifying agents)

**Carbon Analytical Procedures.** When total carbon in nitrogen contg compds or compds (such as expls or proplnts) is detd by combustion in a glass tube contg CuO (method of Dumas), there is always the possibility that oxidation of C to $CO_2$ will accelerate to such an extent that the sample will expl or defgr (thus destroying the combustion tube) even when the sample is previously mixed with materials retarding combustion such as benzophenone proposed by Jovinet et al, (Ref 8). Modifications of method of Dumas proposed by Boivin (Ref 6) or by Courtecuisse (Ref 9) are not always applicable to expls or proplnts

Less dangerous is the method of combustion in a closed bomb (calorimetric bomb) contg a large amt of compressed oxygen, followed by analysis of resulting gas for the amt of $CO_2$ formed on combustion of C. This method was first proposed by Berthelot (Ref 1) and modified by Hempel (Ref 2). Badoche (Ref 3) and Burlot (Ref 4) investigated the method and found it to be satisfactory

In both Berthelot's method and its modifications, the gases produced on combustion or expln are analyzed after they are removed from the bomb. Thomas (Ref 10) found that it is simpler to analyze the gases directly in the bomb without transferring them to another vessel. This method is essentially as follows:
*Procedure:* Place on the bottom of a calorimetric bomb of 500ml capacity, 50ml of 20% KOH and suspend a sample in the form of a compressed tablet (ca 0.8g weighed to 1/10th mg), together with an igniter consisting of a bridge wire enclosed in NC, previously weighed. Close the bomb and introduce compressed oxygen until the pressure inside the bomb reaches 25kg/cm². Ignite the sample by switching the current on in the same manner as when detg the heat of combustion. After cooling the bomb, wipe it off and roll on a flat surface for 5mins to insure that all $CO_2$ is absorbed by KOH. Open the release valve slightly and allow some of the gas to bubble thru a Ba hydroxide soln. If no turbidity appears, it means that all $CO_2$ in the bomb has been asborsed by KOH. If there is turbidity, roll the bomb for an addnl 5mins and then test again

Allow all the gas to escape into the atmosphere. Remove the cover and wash it with distd w into a 25ml volumetric flask with the aid of a funnel. Transfer (quantitatively) the contents of the bomb into the same flask and fill it with w to mark. After mixing the contents, pipet a 50ml aliquot into a tall beaker and titrate with std HCl soln using successively two indicators, first phpht and then methyl orange
*Calculation.* If reading with phpht indicator is n and with methyl orange n', then

$\%C = [6.005(n'-n)f-26p]/P$, where f is normality of HCl (usually 0.5), p the wt of NC used for igniting the sample and P the wt of sample taken

Free carbon (such as carbon black or graphite) in colloidal proplnts can be detd by several methods. The gravimetric method described in Ref 14 is essentially as follows
*Procedure:* a)Place a 5g finely divided sample in a 400ml beaker, add 75ml of concd nitric acid, ACS grade, and cover with a watch glass b)Heat on the steam bath until reaction starts. Remove from the bath and wait until the reaction subsides c)Replace the beaker on the bath and allow the mixt to digest for 1hr d)Remove from the bath, chill in an ice box, add 75ml distd w, and allow to stand until the major part of carbon black has settled out e)Filter the supernatent liquid very slowly thru the tared crucible with asbestos filter, using gentle suction f)Transfer quantitatively the residue in the beaker to crucible and rinse the beaker and contents of the crucible with distd w until most of the acid is removed g)Continue gentle suction for 5mins and discard the filtrate h)Dry the crucible in the oven for 30mins at 100° and cool it to RT without placing in a desiccator i)Without weighing the crucible, rinse its contents with solvent contg 1 vol of acet & 2 vols of ether (using gentle suction) until the filtrate becomes colorless j) continue to aspirate gently until the disappearance of odor of solvent, then dry the crucible in an oven at 125±5° for 30mins, cool in a desiccator and weigh k)Place the crucible in a muffle furnace at 600–650° and leave until all carbonaceous material has been burned l)Remove the crucible from the furnace, cool in a desiccator to RT, and weigh m)Det the loss in wt of the crucible after ignition and calc this loss as the percentage of C in the proplnt on a volatiles-free basis

Donovan (Ref 8a), did not think that the

gravimetric method using nitric acid was accurate enough and he proposed a photometric method, in which the absorption of light by solns in acetone of the unknown and a standard proplnt contg C black is measured at wavelengths such that the absorption by other constituents of proplnt is very small. The percentage of C in the unknown is calcd from that in the standard by the application of Beer's law to the absorption data

A similar method is now included as a Military Standard (Ref 15), but accdg to Liszt (Ref 17), it is applicable only when calibration is done with carbon black identical with that used in the manuf of the proplnt under test

The gravimetric method using nitric acid has been also used in France, but Parpaillon et al (Refs 11 & 12) prefer to use concd hydrogen peroxide in alkaline soln instead of nitric acid. They came to the conclusion to try using $H_2O_2$ after reading in Ref 7 the description of method of Drs E. & W.Berl, who decompd the nitrocompds by means of 30% $H_2O_2$ in alk soln. Parpaillon et al slightly modified the method of Berl and applied it to detn of graphite or carbon black in proplnts

*Procedure of Parpaillon for Detn of C in NC-NG Propellant:* a)Place an accurately weighed 2g sample of proplnt in an Erlen fl, add ca 4ml alc, 15ml distd w and 25ml concd $H_2O_2$ (ca 30%) b)Add 25g KOH in pellets, while gradually cooling the flask with tap w and then heat the flask on a water-bath at 75° until the liq becomes nearly clear c)Cool to RT, add 30ml $H_2O_2$ and heat for 5mins at 75° d)Add another 30ml $H_2O_2$ and heat for 5mins e)Cool and add a few mg of EtCentr (to facilitate the transfer of C from w to ether layer as in operation g) f)Boil the mixt for 10mins, cool to RT, dilute with 100ml distd w and add concd HCl until the liq becomes distinctly acidic g)Transfer the mixt quantitatively to a 1000ml separatory funnel provided with a stopper and add 100ml of ether. Close the funnel and shake in order to transfer the carbon from w to ether layer h)If all C went to the ether layer, discard the aq layer and run the ether layer thru a tared sintered glass crucible of small porosity contg a disc of filter, paper i)Dry the crucible and weigh

*Note:* If carbon does not separate from aq layer or adheres strongly to the walls of the separatory funnel, add a small amt of a wetting agent (such as Na sulforicinoleate), shake the funnel and proceed as in opns h & i

Detn of charcoal in BkPdr by methods used at Bofors Labs (Sweden) and at PicArsn Lab (Dover, NJ) is described under Black Powder, Analytical Procedures

Detn of carbon in expls and proplnts as practiced at PicArsn has been described in several CLR (Chemical Laboratory Reports) and then later in GLR (General Laboratory Reports). Most of these repts are not available, however, accdg to Reese (Ref 16)

The methods for detn of carbon in these repts involve the solution of all other ingredients present in expls or proplnts by various solvents and weighing the residue as carbon. Carbon black is distinguished from graphite by appearance, ease of ignition or by x-ray diffraction pattern (Ref 16)

*Refs:* 1)M.Berthelot, CR **114**, 317-18(1892) & **129**, 1002-5(1899); JCS **62** I, 753(1892) & **78** II, 172(1900)(Analysis of org substances by combustion in compressed oxygen in calorimetric bomb) 2)W.Hempel, Ber **30**, 202-11(1897) & JCS **72** II, 189(1897)(Elementary analysis under pressure in a closed bomb) 3)M.Badoche, Bull Fr [5], **4**, 232(1937)(Combustion of nitrogenous substances in calorimetric bomb) 4)E.Burlot, MP **29**, 226-79(1939)(Study of calorimetry of expls) [Errata for this paper are given in MSCE **30**, 275-9(1943)] 6)A.Boivin, MSCE **30**, 9-13 (1943)(Detn of C & H in compds contg N) 7) Clift & Fedoroff, vol 3, suppl No 2 (1944), Errata & Additions, p 18 (to vol 1, chap 2) 8)P.Jovinet & S.Courtecuisse, MSCE **32**, 16-20 (1945)(Modification of Duma's method) 8a) J.JDonovan, OSRD Rept **5842**, NDRC, Div 3, Secn H, Series P (1945) 9)S.Courtecuisse, MSCE **36**, 147-50(1951)(Modification of Boivin's method described in Ref 6) 10) M.Thomas, MP **34**, 401-11 (1952)(Rapid method of detn of C) 11)M.Parpaillon, MP **34**, 419-20 (1952)(Detn of C black as a residue after destruction of other ingredients of double-base proplnts by treating with hydrogen peroxide in alkaline soln) 11a)"ASTM Standards" (1955), Part 4, **D 561-46**, p 45(Specs & tests for carbon blk) 12)M.Parpaillon & S.Rigal, MP **37**, 305–17 (1955)(Detn of graphite in proplnts by methods similar to that described in Ref 11) 12a) S.Lader, PATR **2409**(1957)(Detn of carbon in inert org expl intermediates) 13)USSpecifications: a)Acetylene Black, MIL-A-3850, superseding PXS-1281 b)Charcoal for Use in Ammunition JAN-C-178A(1) and c)Graphite for Use in Ammunition JAN-G-155(1) 14)Military

Standard MIL-STD-286A, Method 309.1.2, Carbon Black (Gravimetric Method) 15) Military Standard MIL-STD-286, Method 309.2.2, Carbon Black (Photometric Method) 16)E.Reese, PicArsn, private communication (1962) 17) N.Liszt, PicArsn, private communication(1962)

**Carbonaceous Material.** Any material relating to or contg C such as woodmeal, sawdust, cereal flours, lignite, coal, peat, bark, cork & etc. It is used as the fuel ingredient of composite expls

**Carbonates and Bicarbonates.** Carbonates are the salts of carbonic acid and contain the $CO_3$= radical. Bicarbonates, also called acid carbonates, are salts contg the monovalent radical $HCO_3$- . All carbonates are readily decompd by acids; carbonates of the alkali metals are sol in w, giving an alkaline reaction; all others are insol in w (Ref 5,pp 168-9 & Ref 7). Carbonates are formed by the action of $CO_2$ on a soln of alkali, but if excess of the gas is passed into the soln, a bicarbonate results. Bicarbonates are sol in water, and easily decompd by heat with the reformation of the normal carbonate

Some of the carbonates used in expls or pyrotechnics include the following:

*Ammonium Carbonate,* $(NH_4)_2CO_3$; mw 96.09, col cryst plates; sl toxic (Ref 12,p 275). See also Spec MIL-A-13938. DeMent (Ref 14) used this compd in smoke producing compns; and Stevenson (Ref 11) used it to vaporize diphenylchloroarsine & other smokes

*Barium Carbonate,* $BaCO_3$; mw 197.37, wh powd, mp 1740 at 90atm, bp dec, d 4.43; this compd is poisonous when ingested (Ref 12,pp 331-2). It is used in expl mixts & in pyrotechnics. (See also Spec JAN-B-624)

*Calcium Carbonate*(also called Calcite or Aragonite), $CaCO_3$; mw 100.09, mp dec 825° and 1339° at1025 atm, d 2.70-2.95; $Q_f^v$ 2886cal/g (Ref 10); sl toxic (Ref 12,p 425-6). This compd has been used in expl mixts, pyrotechnics, and as a stabilizer for NC (Refs 1 & 3)(See also Spec JAN-C-293)

*Lead Carbonate*(also called Cerussite), $PbCO_3$; mw 267.22, wh powd, mp dec 315°, d 6.6; this compd is poisonous (Ref 12,pp 816-17). It has been used in proplnts and it is claimed by Hennining (Ref 2) that fouling of gun barrels is lessened by addg 1-5% of $PbCO_3$ to proplnt compns

*Lead Carbonate, Basic*(also called White Lead or hydrocerussite), $2PbCO_3 \cdot Pb(OH)_2$; mw 775.67, wh amor powd, mp dec 400°, d 6.14; poisonous compd (Ref 12,pp 816-17). See also Spec MIL-L-18618 (1)

*Magnesium Carbonate*(also called Magnesite or Magnesia Alba), $MgCO_3$; mw 84.32, col rhmb powd, mp dec 350°, d 3.04 (Ref 5,p 505). (See also Spec MIL-M-11361A)

*Manganese Carbonate*(also called Dialozite or Rhodochrosite), $MnCO_3$; mw 114.9, rose-colored rhmb crysts, mp dec on heating, d 3.13 (Ref 5,p 512). (See also Spec MIL-M-13667)

*Potassium Carbonate*(also called Potash or Sal Tartar), $K_2CO_3$; mw 138.2, col monoclinic crysts, mp 900° (dec), d 2.2 (Ref 5,p 677). It is used as a reagent, in photography, in medicine, and in the prepn of K picrate, a primary expl (Ref 4,p 5). (See also Spec O-P-552C)

*Sodium Carbonate*(also called Soda, Washing Soda or Soda Ash), $Na_2CO_3$; mw 106.00, wh crysts, mp 851°, bp dec on further heating, d 2.48 (Ref 5,p 780 & Ref 12,p 1114). It is used as a reagent, in the manuf of various chem products & in other industries, and in various expl compns. (See also Spec O-S-571E)

*Strontium Carbonate*(also called Strontianite), $SrCO_3$; mw 147.6, col rhmb crysts, mp dec 1155°, d 3.62 (Ref 5,p 811)

*Zinc Carbonate, Basic*(also called Tutia), $ZnCO_3 \cdot H_2O$; mw 143.40, wh rhmb crysts, mp dec 300°, d 4.42 (Ref 5,p 922). See also Spec MIL-Z-12061. The anhyd salt is listed in Sax,p 1267

The principal bicaronates used in expls include the following:

*Ammonium Bicarbonate,* $NH_4HCO_3$; mw 79.1, col rhmb or monoclinic crysts, mp dec 40-60°, d 1.59 (Ref 5,p 47). It is used in some compns(Ref 6)

*Potassium Bicarbonate,* $KHCO_3$; mw 100.1, col transparent monoclinic crysts, mp dec on heating, d 2.17 (Ref 5,p 676). It is used as a combustion controlling agent in some pyrotechnic smoke compns (Ref 8). (See also Spec MIL-P-3173)

*Sodium Bicarbonate*(also called Acid Sodium Carbonate or Baking Soda), $NaHCO_3$; mw 84.01, wh opaque powd or col crysts, mp dec 270°, d 2.21 (Ref 5,p 779); $Q_f^v$ 2680cal/g (Ref 10). See also Spec O-S-576B. It was used in a type of permissible expl, contg large amts of $NaHCO_3$ & small amts of NG, called Bikarbit (Ref 13). Mixts contg as much as 95% $NaHCO_3$ and as little as 5% NG were still easy to initiate by ordinary blasting caps. Donlan (Ref 9) reported that $NaHCO_3$, when added to cellulose material,

acts as a flame retarding agent
*Refs:* 1)Marshall **1**(1917), 186 & **2**(1917), 641 2)C.Henning, USP 1357865(1920) & CA **15**, 315 (1921) 3)P.Demougin & M.Landon, MP **27**, 182 -89(1937) & CA **31**, 8200(1937) 4)Davis (1943) 5)Hackh's(1944) 6)Kast-Metz(1944), 20 7) Partington(1950), 623 8)L.Finkelstein & S.J.Magram, USP 2543006(1951) 9)J.E.Dolan, Chem & Ind **1952**, 368-71 & CA **46**, 7330(1952) 10)P.Tavernier, MP **38**, 312, 332(1956) 11) R.Stevenson, USP 2730482(1956) & CA **50**, 15008(1956 12)Sax(1957) 13)PATR **2510** (1958),p Ger **11** 14)J.DeMent, USP 2995526 (1961)

**Carbonation.** 1)See Carbonization 2)The precipitation of lime by $CO_2$, as in sugar refineries 3)The saturation of water with $CO_2$, as in soda water manuf; more properly known as *carbonatation*
*Ref:* Hackh's (1944), 169

**Carbon Bisulfide.** Same as Carbon Disulfide

**Carbon Black.** See under Carbon

**Carbon Carbonite.** An expl compn: K nitrate 34, NG 25, wheat flour 38.5, Ba nitrate 1, ground tan 1 & soda ash 0.5%
*Ref:* CondChemDict(1942), 288 (not found in later editions)

**Carbon Dioxide or Carbonic Anhydride,** $CO_2$; mw 44.01; col,odorless gas or a wh snowlike solid called "dry ice", fr p -57° at 5.2 atm, bp -78° (sublimes), d 1.56 at -79°(solid), d 1.10 at -37° (liq), d 1.53 at RT(gas); sol in w, sl sol in alc; MAC 5000 ppm in air or 9000 mg/cu meter in air. Carbon dioxide in generally regarded as a simple asphixant; signs & symptoms preceeding asphixia are headache, dizziness, shortness of breath, muscular weakness, drowsiness & ringing in the ears. Removal from exposure to $CO_2$ results in rapid recovery. Contact of $CO_2$ snow(dry ice) with the skin can cause a burn (Ref 12). See also Rumpel(Ref 10) and Miller et al(Ref 11)

Carbon dioxide issues in abundance from the earth, it occurs in mineral springs, it is formed during respiration of mammals and passes into the atmosphere, and is evolved in the fermentation process & in the decay of org matter. It is produced commercially from the decompn of carbonates, by the combustion of carbonaceous materials such as coke, coal, oil & natural gas and as a by-product in the manuf of ethyl alcohol by yeast fermentation of carbonhydrates (Refs 1,3,6,8,9 & 13). It is shipped as cubical blocks(dry ice) in special refrigerated cars & trucks and as a compressed liq in steel cylinders or tanks

This compd is used extensively in many industries: for example, in carbonating beverages, as a refrigerant, in fire extinguishers, for the destruction of vermin, as a fertilizer, and in the explosives industry. According to Ferrell et al (Ref 2), blasting operations may be conducted by gasifying a chge of liq $CO_2$ in a closed cartridge by heat produced on vaporization of an elec conductor. Williams(Ref 4) used solid $CO_2$ as a tamping chge with various blasting chges loaded into bore holes. The use of a device for blasting, with a mixt of $CO_2$ & $H_2O$ both in the form of snow, is described by Weber(Ref 5). The mixt is heated to cause its instant vaporization when desired. Podbel'skii & Ermuzevich(Ref 7) patented a heating compn, constg of a mixt of naphthalene & $KClO_3$ which was ignited electrically and used to detonate solid $CO_2$ expls (see also Cardox Blasting Cartridge). In the form of dry ice, carbon dioxide is used extensively in chem labs
*Refs:* 1)Mellor **6**(1925), 1-78 2)D.Ferrell et al, USP 1610274(1926) & CA **21**, 497(1927) 3) Pepin Lehalleur(1935), 360-62 4)V.H.Williams, USP 2031084(1936) & CA **30**, 2388(1936) 5) G.Weber, USP 2102245(1937) & CA **32**, 1456(1938) 6)Thorpe **2**(1938), 323-28 & **8**(1947), 547 6a) Davis(1943), 277, 323 & 326 7)G.N.Podbel'skii & D.V.Ermuzevich, RussP 65029(1945) & CA **40**, 7633(1946 8)Kirk & Othmer **3**(1949), 125-42; **7**(1951), 855 & 1st Supplement (1957), 36, 497, 512, 515, 524, 892, 895 9)Partington (1950), 618-22 10)W.Pumpel, MittChemForsch-InstInd Österr **4**, 113-17(1950) & CA **45**, 2603(1951) 11) F.A.Miller et al, SurgForumProc 37th ClinCongr AmCollSurgeons **1951**, 35-40(1952) & CA **47**, 1296(1953) 12)Sax(1957), 436-37 13)Faith, Keyes & Clark (1957), 219-27

**Carbon Disulfide and Derivatives**

**Carbon Disulfide or Carbon Bisulfide**(called Schwefelkohlenstaff, Kohlendisulfid or Dithiokohlensäureanhydrid in Ger), $CS_2$, mw 76.13; col liq nearly odorless when pure, fr p -111°, bp 46.5°, fl p -22°F(cc), d 1.261 at 20°, autoign temp 257°F, vap press 400mm at 28°, vap d 2.64; sol in alc or eth; nearly insol in w(Refs 1 & 16). The MAC is 20ppm in air or 62mg/cu meter of air. The chief toxic effect of $CS_2$ is on the central

nervous system; it acts as a narcotic & anesthetic in acute poisoning with death following from respiratory failure. Its anesthetic action is much more powerful than that of chloroform. In chronic poisoning, the effect of $CS_2$ on the central nervous system is one of central & peripheral damage which may be permanent if the damage is severe(Ref 16). See also Amor (Ref 11) & Rumpel (Ref 12)

Carbon disulfide is produced by reacting charcoal & sulfur in the presence of heat furnished by electrothermal or retort methods. Another process has been developed in which natural gas is used as the source of carbon. With a catalyst such as activated alumina, $CS_2$ in yields of 90% may be produced by reacting 1 mole methane(natural gas) with 2 moles sulfur at approx 700°(Ref 17)(See also Refs 7,10,13 & 15)

Liempt & deVriend(Ref 3) conducted studies on the expln of $CS_2$-NO, $CS_2$-$N_2O$ and of $CS_2$-$N_2O$-NO mixts. The expl props of a mixt of $CS_2$ & $NO_2$, called "Myrite", was investigated by Bain(Ref 5) but due to its relative sensitivity to rifle bullet impact and its relatively low rate of deton & brisance was not considered favorably as a military expl. The flammability of $CS_2$ in mixts of air & water vapor was studied by Zabetakis & Jones(Ref 14) who found that the min amt of O reqd for the mixt at 100° & 1atm press is 7.6% by vol. According to Roedler(Ref 9), the danger of expln & fire is great in the use and storage of $CS_2$ (See also Refs 1,2 & 8)

Carbon disulfide is used in viscose rayon, cellophane,for the manuf of carbon tetrachloride, in veterinary medicine; as a solv in paints, rubber, textiles, matches; and as a fumigant, preservative & pesticide(Refs 6 & 18). It is highly dangerous when exposed to heat, flame, sparks or friction.

*Refs:* 1)Beil **3**, 197, (179), [139] & {320ff} 2)Mellor **6**(1925), 94–118 3)J.A.M.vanLiempt & J.A.deVriend, Rec **52**, 160-68, 862-68(1933) & Rec **53**, 760-68(1934) 4)Thorpe **2**(1938), 328-44 5)C.J.Bain, PATR **1030**(1940) 6)Davis(1943), 48,119,225,227,354 & 438 7)A.Towers, SchoolSciRev **29**, 307-10(1948) & CA **43**, 2826 (1949)(A short review on production & uses) 8) Kirk & Othmer **3**(1949), 142-48 9)F.Roedler, Desinfekt u Schädlingsbekämpf **41**, 211–14(1949) & CA **46**, 11564(1952) 10)ResInfoService Rept No **95810**, Translation of Ger Pat Application No 34369D(Feb 1949)(Process for producing carbon disulfide by heating methane with $H_2S$) 11) A.J.Amor, Paint Manuf **20**, 89-93(1950) & CA **44**, 4165(1950) 12)W.Rumpel, MittChemForsch -InstInd Österr **4**, 113-17(1950) & CA **45**, 2603 (1951) 13)Partington (1950), 635-37 14) M.G.Zabetakis & G.W.Jones, IEC **45**, 2079-80 (1953) & CA **47**, 11737(1953) 15)E.Charles, USP 2670277(1954) & CA **48**, 4784(1954)(Apparatus for continous production of carbon disulfide) 16) Sax(1957), 437-38 17)Faith, Keyes & Clark (1957), 228-32 18)CondChemDict (1961), 219

**Carbon Disulfide Monoazide**, $N_3.CS_2H$. This compd is described in Vol 1,p A632-L as *Azidodithiocarbonic Acid.* Lieber et al (Ref 2) assigned to it(based on IR spectra), the thiatriazole structure, , naming it

*4H,1,2,3,4-thiatriazoline-5-thione*

*Refs:* 1)Beil **3**, (86), [159] & {356} 2)E.Lieber et al, JOC **22**, 1750(1957)

**Carbon Disulfide, Azido Derivative.** A misnomer for Bis-(azidothioformyl)-disulfide(qv)

**Carbonic Acid**, $H_2CO_3$. The soln of $CO_2$ in $H_2O$ exhibits feeble acid props; it is unstable, however, and has never been isolated; it is known only in the form of its salts (*carbonates*), acid salts (*bicarbonates*), amides (*carbamic acid or urea*), and as acid chlorides (*carbonyl chloride*). This is also an old term for *carboxylic acid*

*Ref:* Hackh's(1944), 169

**Carbonic Acid, Azidothio Derivatives.** See Vol 1, p A632ff of this Encyclopedia

**Carbonic Anhydride.** See Carbon Dioxide

**Carbonides.** See Carbides

**Carbonites.** Permissible straight dynamites used in Germany(Refs 2 & 4), GtBritain (Ref 2,p 402) and at one time in the US(Ref 3,p 351). In France they were used in modified formulations under the names of "Grisoutines"(Ref 1 & Ref 2,p 402)

The principal components of Carbonites are: NG(gelatinized or not with collod cotton), K or Na nitrate and spent tan bark or woodmeal. Some Carbonites contain Ba nitrate, K bichromate, Amm oxalate, gelatinized silicic acid and soda ash or Mg carbonate

Typical Ger Carbonits are listed in Ref 2,p 401, Ref 3,p 353 & Ref 4,p 26. Typical Brit Carbonites are listed in Ref 2,p 402(See also

Carbon Carbonite, Coal Carbonite, Gelatin Carbonite, Kohlencarbonit, Haylite No 1, Oaklite No 1 and Phoenix Powder

The Ammoncarbonit is described in Vol 1, p A293 of this Encyclopedia

*Refs:* 1)H.Dautriche, MP **15**, 120-22(1909-10) 2)Naoúm, NG(1928), 401-2 3)Davis(1943), 351-3 4)PATR **2510**(1958), 25-6

**Carbonization.** 1)The transformation of org matter into charcoal 2)The distillation of coal, as in gas & coke manuf(Ref 1). See also Refs 2 to 7, incl

*Refs:* 1)Hackh's (1944), 169 2)I.V.Gebler, IzvestAkadNauk, OtdelTekhNauk **1948**, 873-82 & CA **44**, 4228(1950)(Coking of the gas coals of the Kusnetsk coal fields) 3)A.Thau, "La Distillation à Basse Température des Combustibles", W.Knapp, Halle(1949), 222pp; Reviewed in JUsines-Gaz **74**, 259(1950) 4)Y.Mayor, "Combustible Solids", SocProds Documentaires, Paris (1950), 232pp; Reviewed in JUsines Gaz **74**, 259(1950) 5)H.Winter, "Taschenbuch für Gaswerke, Kokereien, Schwelereien, und Teerdestillationen", 6 ed, W.Knapp, Halle(1950), 659pp; Reviewed in Gas- u Wasserfach **92**, 67(1951) 6)K.J.Nelson, USP 2549117(1951) & CA **45**, 5910(1951)(Fluidized carbonization) 7)H.J.vonAlberti, "Der Braunkohlenschweler" (Böhlener Schwelfibel), W.Knapp, Halle(1951), 79pp; Reviewed in Braunkohle **4**, 92(1952)

**Carbonize.** To convert to carbon; to char or burn incompletely

*Ref:* Hackh's(1944), 169

**Carbon Monoxide,** CO; mw 28.01; col & odorless gas, fr p -199°, bp -190°, d(gas) 1.250g/liter at 0°, d(liq) 0.793, vap d 0.967, autoign temp 1204°; sl sol in w; readily absorbed by a soln of cuprous chloride in HCl or in $NH_3$; its MAC is 100 ppm in air or 115mg/cu meter of air. Carbon monoxide has a great affinity for hemoglobin of the blood and by combining with it renders the blood incapable of carrying oxygen to the tissues. Concns from 30 to 50% CO cause severe headache, mental confusion, impairment of vision & collapse or fainting; 50 to 60% cause unconsciousness & death if exposure is long; concns of 80% result in almost immediate death(Ref 20)(See also Refs 1, 2,5,8 & 9)

Carbon monoxide is obtained almost pure by introducing a mixt of O & $CO_2$ in contact with incandescent graphite, coke or anthracite; by action of steam on hot coke or coal (water gas reaction); as a by-product in chem reaction; and by combustion of org compds with a limited amt of O (Ref 21). A lab method for the prepn of pure CO from formic acid & concd $H_2SO_4$ is described in Ref 3(See also Refs 1,2,5,6,7,10 & 16)

Carbon monoxide burns in air or O with a bright blue flame, forming $CO_2$. A mixt of 2 vols CO & 1 vol O expl when ignited by a spark. The dry gases do not expl unless a trace of moisture, or a gas which contains H and so produces $H_2O$ on combustion in O, is present. This expl reaction has been studied by a number of investigators(Refs 4,11,12,14,15,17,18 & 19). The spontaneous ignition of CO and some of the factors controlling it are discussed by Warren(Ref 13)

Carbon monoxide is used in org synthesis, as a fuel, in metallurgy, and in Zn white pigments(Ref 21). More details of uses of CO are given by Kirk & Othmer (Ref 5)

*Refs:* 1)Mellor **5**(1924), 904ff 2)Thorpe **2**(1938), 344–51 2a)Davis(1943), 276-7, 323,327 & 352 3)Inorg Synth **2**(1946), 81-5 4)S.H.Ash & E.W.Felegy, US Bur Mines Bull No **47**(1948), 202 pp & CA **44**, 4679(1950) 5)Kirk & Othmer **3** (1949), 179-91 6)W.Reppe, Experientia **5**, 93-110 (1949) (Recent developments in the chemistry of acetylene & CO) 7)Partington(1950), 627-31 8) A.Grut, "Chronic Carbon Monoxide Poisoning", Munskgaard, Copenhagen (1950), 229pp; Reviewed in RassMedInd **19**, 295(1950) 9) W.Rumpel, MittChemForsch-InstÖsterr **4**, 113-17 (1950) & CA **45**, 2603(1951) (Causes & prevention of poisoning in chem plants) 10)J.Schmidt, "Das Kohlenoxyd", Geest & Portig, Leipzig(1950), 366pp 11)G.B.Kistiakowsky et al, JChemPhys **20**, 994-1000(1952) & CA **47**, 1931(1953) 12) R.E.Duff & H.T.Knight, JChemPhys **20**, 1493-95 (1952) & CA **46**, 11688(1952) 13)D.R.Warren, Fuel **33**, 203-8(1954) & CA **48**, 6126(1954) 14) J.P.Toennies & H.G.Wagner, ZElektrochem **59**, 7-15(1955) & CA **49**, 8602(1955) 15)H.G.Wagner, ZElektrochem **59**, 906-9(1955) & CA **50**, 4508 (1956) 16)P.A.Paramonov, GornyiZh **1955**, No 10, 49-55 & CA **50**, 6049(1956)(Mechanism of CO formation in mine air during blasting) 17) A.S.Gordon & R.H.Knipe, JPhChem **59**, 1160-65 (1955) & CA **50**, 2174(1956) 18)W.Roth et al, JPhChem **60**, 512(1956) & CA **50**, 12481(1956) 19)F.Otásek, Uhlí (Czechoslovakia) **6**, 90-3 (1956) & CA **50**, 11018(1956) 20)Sax(1957), 438-39 21)CondChemDict (1961), 220

**Carbon Pernitride.** See Cyanazide under Cyno Compounds and Derivatives

**Carbon Tetrabromide** (called Tetrabrommethan, Kohlenstofftetrabromid or Tetrabromkohlenstoff in Ger), $CBr_4$; mw 331.67; col monocl crysts, mp (alpha) 48.4° & (beta) 90.1°, bp 189.5°, d 3.42, vap press 40mm at 96.3°; sol in alc or eth; insol in w. Other props & methods of prepn are given in Refs

*Refs:* 1)Beil **1**, 68, (17), [35] & {92} 1a)Davis (1943), 375 2)Hackh's(1944), 168 3)D.E.Lake & A.A.Asadorian, USP 2553518(1951) & CA **46**, 2561(1952) 4)Sax(1957), 440

**Carbon Tetrachloride**(called Tetrachlormethan, Kohlenstofftetrachlorid or Tetrachlorkohlenstoff in Ger), $CCl_4$; mw 153.84, col liq having a heavy ethereal odor, fr p -22.6°, bp 76.8°, d 1.597 at 20°, vap press 100mm at 23°; sol in alc, eth, chlf, benz or petr eth; v sl sol in w; MAC 25ppm in air or 157mg/cu m of air(Refs 1 & 20). Carbon tetrachloride has a narcotic action resembling that of chloroform, although not as strong. Exposure to high concns of $CCl_4$ may cause unconsciousness & even death if exposure is not terminated; lower concns result in severe gastro-intestinal upset, serious kidney or hepatic damage(Ref 20)(See also Refs 3,10,13 & 16)

Carbon tetrachloride is prepd by the interaction of $CS_2$ & Cl in the presence of a catalyst(iron) or by the chlorination of methane or higher hydrocarbons at 250-400°(Ref 21). See also Refs 1,4,5,9,15,18 & 19. The crude product is purified by treating with caustic soln to remove sulfur chloride, followed by rectification

It is, itself, a nonflammable liq. Flash, fire & expln tests on mixts of $CCl_4$ & naptha, as detd by Barrier(Ref 2), showed that they are combustion and expln-proof if such mixts contain a min amt of $CCl_4$. This amt varies, with the sp gr of petr naptha, from 30 to 70%. The quenching power of $CO_2$, $CCl_4$, $CH_3Br$ & $CH_2ClBr$ for fires of org combustible liquids and of wood shavings was detd by Hoogstraten & Van Elteren(Ref 12) who found that quenching power increased in the foregoing order of agents, although the type of fuel was also of importance

Expl reactions have been reported in two labs working with ethylene & $CCl_4$(Refs 7 & 8). In the lab of the California Res Corp, Richmond, Calif an expln occurred quite suddenly at 67° & >2500 psi after heating ca 2hrs a mixt of $CCl_4$, $C_2H_4$ & a catalytic amt of benzoyl peroxide in a std lab autoclave(Ref 7). Two other examples of uncontrolled reactions between ethylene & $CCl_4$, which resulted in violent explns, occurred in a tubular pressure reactor at the duPont Experimental Station, Wilmington, Del(Ref 8). On one occasion, expln took place at a temp of 94° and a press of 14500psi only 20mins after the reaction started. In the second example the reactor was charged with $CCl_4$, $H_2O$ & $C_2H_4$ and heated with agitation at110° and a press of 9600 psi, a violent expln resulted. In both examples dibenzoyl peroxide was the reaction initiator. Precaution essential for avoiding these explns are given by Joyce(Ref 8). The expln of acetylene mixed with oxygen or air under high press, and the effects of added substances are described by Kiyama et al (Ref 17); addn of $CCl_4$ or water elevates the expln temp, however, when expln does take place it is more violent than without the additives. Lindeijer (Ref 11) reported that a mixt of $CCl_4$ & powd Al resulted in a fatal expln

Carbon tetrachloride is used in refrigerants, in metal degreasing , as grain fumigants & insecticides, in fire extinguishers, as dry cleaning solvents, for chlorinating org compds and as a general solvent(Refs 6 & 21)

*Refs:* 1)Beil **1**, 64, (12), [22] & {64} 2) E.A.Barrier, IEC **2**, 16-19(1910) & CA **4**, 669 (1910) 3)Kohn-Abrest, AnnChimAnalChimAppl **15**, 199-207(1933) & CA **27**, 3193(1933)(Props of $CCl_4$, toxicity, detection in air, decompn by heat & its behavior on analysis are described) 4)Mellor **13**(1934), 615 5)Thorpe **2**(1938), 353-56 5a) Davis(1943), 145,152,181,216,398,402-3 & 447 6) Hackh's(1944), 168 7)R.O.Bolt, C & EN **25**, 1866(1947) & CA **41**, 5724(1947) 8)R.M.Joyce, C & EN **25**, 1866-67(1947) & CA **41**, 5724(1947) 9) Kirk & Othmer **3**(1949), 191-200 10) W.F.VonOettinger et al, ArchIntern Pharmacodynamie **81**, 17-34(1950) & CA **44**, 7426(1950) 11) E.W.Lindeijer, ChemWeekblad **46**, 571(1950) & CA **46**, 7769(1952) 12)C.W.Van Hoogstraten & J.F.Van Elteren, ChemWeekblad **47**, 866-75(1951) & CA **46**, 2805(1952) 13)R.W.Van Hoesen Korndorffer, Plastica(Delft) **4**, 11-13(1951) & CA **49**, 11178-79(1955) 14)E.H.Coleman, "A Comparison of the Extinguishing Effects of Chlorobromomethane, Methyl Iodide and Carbon Tetrachloride", Fire Protection Assoc, London (1952), 12pp 15)N.Trappeniers, "Le Principe des États Correspondants et les Diagrammes d'État du Tétrachlorure et du Tétrabromure de Carbon", Palais Acad, Brussels(1952), 93pp 16) C.C.Comstock & F.W.Oberst, Arch Ind Hyg Occupational Med **7**, 157-67(1953) & CA **47**, 12618-19(1953) 17)R.Kiyama et al, RevPhysChem-Japan **24**, 41-48(1954) & CA **49**, 12006(1955) 18)

L.F.Hatch, Petroleum Refiner **33**, No 12, 136-40 (1954)(A review of production rates, processes and end uses of chlorinated $C_1$'s & $C_2$'s) 19) Faith, Keyes & Clark(1957), 233-37 20)Sax (1957), 440-41 21)CondChemDict(1961), 220

**Carbon Tetrafluoride**(called Tetrafluormethan, Kohlenstofftetrafluorid or Tetrafluorkohlenstoff in Ger), $CF_4$; mw 88.01; col gas, fr p -184°, d 1.96 at -184°; formed as a by-product in the manuf of Al from cryolite (Ref 2); can be prepd by the action of F on SiC(Ref 3). Other props & methods of prepn are given in Refs
*Refs:* 1)Beil **1**, 59, (8), [11] & {35} 2) Hackh's(1944), 168 3)H.F.Priest, InorgSynth **3** (1950), 171 4)R.M.Mantell et al, USP 2684987 (1954) & CA **49**, 10354(1955) 5)M.W.Farlow, USP 2709182(1955) & CA **50**, 6506(1956) 6) E.L.Muetterties, USP 2709184(1955) & CA **50**, 6498(1956) 7)M.W.Farlow & E.L.Muetterties, USP 2709191(1955) & CA **50**, 6507(1956) 8)Ibid, USP 2732410 & 11(1956); CA **50**, 15574(1956) 9)Sax (1957), 441-42

**Carbon Tetraiodide**(called Tetraiodmethan, Kohlenstofftetraiodid or Tetraiodkohlenstoff in Ger), $CI_4$; mw 519.69; octahedral red crysts, mp 171° (dec), d 4.32 at 20°; sol in alc or eth; insol in w(Refs 2 & 5); other props & methods of prepn are given in Refs 1 & 4. It has been investigated, in addn to other tetriodo or related compds, for its possible fungistatic activity(Ref 3)
*Refs:* 1)Beil **1**, 74, (19), [39] & {104} 2) Hackh's(1944), 168 3)I.Muirhead, AnnApplied Biol **36**, 250-56(1949) & CA **44**, 10233-35(1950) 4)R.E.McArthur & J.H.Simmons, InorgSynth **3** (1950), 37 5)Sax(1957), 442

**Carbonyl Azide.** See Carbonyl Diazide, Vol 1,p A528-L

**o-Carbonylazido-diphenylurea**{called 2-[ω -Phenyl-ureido]-benzoesäure-azid or N-Phenyl -N'-[2-azidoformyl-phenyl]-harnstoff in Ger}, $C_6H_5.NH.CO.NH.C_6H_4.CO.N_3$; mw 281.27, N 24.90%; crysts (from MeOH), mp 133°, detonates violently when heated in a flame; was prepd by heating aniline with 2-azidoformylphenylisocyante (itself a violent expl when heated rapidly; See Vol 1,p A638-R) in benz
*Refs:* 1)Beil **14**, [224] 2)H.Lindemann & W.Schultheis, Ann **464**, 251(1928) & CA **22**, 3664(1928)

**Carbonylazido-guanidine**(called Guanidincarbonsäureazid in Ger), $H_2N.C(:NH).NH.CO.N_3$; mw 128.10, N 65.61%; was obtd in the form of its *Hydrochloride*, $C_2H_4N_6O$+HCl; fine crysts, mp 157°, expl in a flame; very sol in w; insol in org solvs; was prepd by treating a concd aq soln of aminodicyandiamidine dihydrochloride with a chlf soln of anhyd $N_2O_5$
*Refs:* 1)Beil **3**, 130 2)J.Thiele & E.Uhlfelder, Ann **303**, 112(1898)

**(5'-Carbonylazido-pyridine)-1',2':4,5-tetrazole.** See under (5'-Carboxypyrido)-1',2': 4,5-tetrazole

**Carbonyls.** A group of compds of CO & metals, having the general formula $M_x(CO)_y$. They are usually prepd by interaction of CO with heated metals. Most carbonyls are highly toxic and dangerous when heated. Some compds are reported to be expl or very unstable:
*Iron Nonacarbonyl*, $Fe_2(CO)_9$; mw 363.8, orn hex crysts, mp dec 100°, d 2.09 at 18° (Ref 2,p 450 & Ref 6,p 790)
*Iron Pentacarbonyl*, $Fe(CO)_5$; mw 195.9, yel to dk red liq, fr p -21°, bp 105°, fl p 5°F, d 1.453 at 25°, vap press 40mm at 30.3° (Ref 2,p 450 & Ref 6,p 790)
*Iron Tetracarbonyl*, $Fe(CO)_4$; mw 167.88, dk-grn lustrous crysts, mp dec 140-50°, d 1.996 at 18° (Ref 2,p 450 & Ref 6,p 791)
*Nickel Carbonyl*, $Ni(CO)_4$; mw 170.69, col volatile liq or ndls, fr p -25°, bp 43, d 1.319 at 17°, vap press 400mm at 25.8°; MAC 1ppm in air or 7mg/m³ in air; expl range 2% at 20°(Ref 2,p 570 & Ref 6,p 933-34). Badin et al (Ref 3) reported that vapors of this compd expl in air or oxygen at 20° and partial pressures as low as 15mm. The expln is preceded by a long & variable induction period
*Potassium Carbonyl* (called Hexaoxybenzolkalium in Ger), $K_6(CO)_6$; mw 402.64, gray-red solid, mp expl on prolonged contact with air or in contact with w; was prepd by passing CO over heated K, and also obtd a by-product in the prepn of K from $K_2CO_3$ (Ref 1; Ref 2,p 677; Refs 4 & 5; and Ref 6,p 1038)
*Sodium Carbonyl*, NaCO; mw 51, highly toxic (no other props are given in Sax, p 1114)
*Refs:* 1)Beil **6**, 1199 2)Hackh's(1944) 3) E.J.Baldin et al, JACS **70**, 2055-56(1948) & CA **42**, 7045(1948) 4)Kirk & Othmer **3**(1949), 201 5) Karrer(1950), 430 6)Sax(1957)

**Carbonylurea**, $OC(NH.CO.NH_2)$; crysts, mp 231-5

(Ref 1). Aaronson(Ref 2) prepd it by heating in an autoclave mixt of oxamine $(CO.NH_2)_2$ & phosgene $CO.Cl_2$. Attempts to nitrate it to obtain mono- or dinitro- derivs were unsuccessful
*Refs:* 1)Beil **3**, 72, (35), & [60] 2)H.Aaronson, PATR **1037**(1940)

**Carborundum.** A trade name for *Silicon Carbide*, SiC, a hard substance(Moh's hardness 9.17), which can be obtained by heating sand and coke with some sawdust in an electric furnace at high temp. The name "carborundum" is also applied to other hard materials, such as fused alumina. These materials are used as abrasives for cutting, grinding or polishing(Refs 2,3,5,6 & 7). To a limited extent, carborundum was used as a component of primers to increase their sensitiviness to friction & impact(Ref 4). Bain(Ref 1) found that incorporation of 5% of carborundum in Tetracene produced a mixt sufficiently sensitive for use as a cover chge for LA in primers
*Refs:* 1)C.J.Bain, PATR **859**(1937) 2)Thorpe **2** (1938), 358-61 3)Hackh's(1944), 169 4)All & EnExpls(1946), 34 5)Kirk & Othmer **2**(1948), 854-66(49refs) 6)Sax(1957), 1100(Props & toxicity) 7)CondChemDict(1961), 221

**Carboxydiphenyl.** Same as Biphenylcarboxylic Acid

**Carboxyhydrocinnamic Acid and Derivatives**

*Carboxyhydrocinnamic Acid or Carboxyphenyl-propionic Acid* [called β-(Carboxy-phenyl)-propionsäure or Hydrozimtsäure-(2,3 or 4)-carbonsäure in Ger], $HOOC.C_6H_4.CH_2.CH_2.COOH$; mw 194.18. Three isomers are described in the literature: β-(2-Carboxyphenyl) deriv, ndls (from w), mp 165-7° (Ref 1); β-(3-Carboxyphenyl) deriv, pltlts, mp 177° (Ref 3); and the β-(4-Carboxyphenyl) deriv, ndls (from alc), mp 277° & 294°, dec ca 280° (Ref 2). Other props & methods of prepn are given in Beil
*Refs:* 1)Beil **9**, 872, (382) & [622] 2)Beil **9**, 873 & [622] 3)Beil **9**, [622]

*Mononitrocarboxyhydrocinnamic Acid*, $HOOC.C_6H_3(NO_2).CH_2.CH_2.COOH$; mw 239.18, N 5.86%. The β-(2-Nitro-4-carboxyphenyl) deriv is described in Beil; crysts, mp 191-2°; readily sol in MeOH; sol in hot w, alc or dil AcOH; insol in benz; was prepd by nitration of the parent compd using mixed acid (Refs 1 & 2)
*Refs:* 1)Beil **9**, 873 2)O.Widman, Ber **22**, 2273(1889)

*Dinitrocarboxyhydrocinnamic Acid*, $HOOC.C_6H_2(NO_2)_2.CH_2.CH_2.COOH$; not found in Beil or in CA thru 1956

**3,4,6(or 3,5,6)-Trinitro-2-carboxyhydrocinnamic Acid**, $HOOC.C_6H(NO_2)_3.CH_2.CH_2.COOH$; mw 329.18, N 12.77%; crysts, mp expl violently on heating; was obtd with other products on nitration of 5,6,8-trinitrotetralin with $KMnO_4$ in acet. Its *Potassium salt*, $KC_{10}H_6N_3O_{10}$, yel crysts, expl violently when heated in a flame (Refs 1 & 2)
*Refs:* 1)Beil **9**, [622] 2)I.G.Schroeter, Ann **426**, 47(1922) & CA **16**, 1764(1922)

**Carboxymethylcellulose**(CMC). A cellulose glycolate compd that has achieved great coml importance in recent years. The *Sodium salt* is its most important deriv: col, odorless, tasteless, non-toxic, hygro powd; combustible when finely ground. The trademark for one tech grade coml product is "Carbose" (Ref 2). Sodium CMC is supplied in several grades, depending upon viscosity & purity. Its prepn is described in Ref 1. It is used as a thickener, binder, stabilizer for emulsions, ingredient of detergents & in film-forming. The *Potassium salt* resembles the Na salt in many of its props. The *Ammonium salt* is unstable and certain metallic salts are insol in water
*Refs:* 1)Groggins(1958), 846-7 2)CondChemDict (1961), 221, 1037

**Carboxyoxanilic Acid.** Same as Carboxyphenyl-oxamic Acid

**[I(or N')-Carboxyphenyl-III(or N)-cyanoguanyl]-triazene or [I(or N')-Carboxyphenyl-III(or N)-cyanoamindino]-triazene** {called 1(oder 3)-[2-Carboxy-phenyl]-3(oder 1)-cyanguanyl-triazen-(1); 2-[Cyanoguanyl-triazeno]-benzoesäure; or [2-Carboxy-benzoldiazo]dicyandiamid in Ger}, $HOOC.C_6H_4.N{:}N.NH.C(:NH).NH.CN$; mw 232.20, N 36.20%; yel crysts (from MeOH), mp dec ca 98°; readily sol in hot alc; sl sol in benz, eth or chlf; insol in w; was prepd by treating diazotized anthranilic acid with dicyandiamid in alksoln. Its *Silver salt*

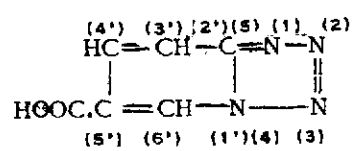
$Ag_2C_9H_6N_6O_2$+ $AgC_9H_7N_6O_2$, yel, gelly like ppt, expl on heating (Refs 1 & 2)
*Refs:* 1)Beil **16**, (410) 2)R.vonWalther & W.Grieshammer, JPraktChem **92**, 235(1915) & JCS **110** I,172(1916)

### Carboxyphenyloxamic Acid and Derivatives

*Carboxyphenyloxamic Acid or Carboxyoxanilic Acid* [called (Carboxy-phenyl)-oxamidsäure or Oxanilsäure-carbonsäure in Ger], $HOOC.CO.NH.C_6H_4.COOH$; mw 209.15, N 6.70%. Two isomers are described in the literature: 2-Carboxy deriv (also called Kynuric Acid), ndls + $H_2O$ (from w), becomes anhyd in vac at 60-70°, mp (of hydrate) 199-200° (dec) and (of anhyd acid) 200-10°; forms numerous salts (Ref 1) and the 3-Carboxy deriv, lfts + $H_2O$ (from w), at ca 210° converts to oxanilide -3,3-dicarboxylic acid (Ref 2). Other props & methods of prepn are given in the refs
*Refs:* 1)Beil **14**, 342, (541) & [222] 2)Beil **14**, 398

**5-Azido-3-carboxyphenyloxamic Acid,** $HOOC.CO.NH.C_6H_3(N_3).COOH$; mw 250.17, N 22.40%; yel substance (from w), readily sol in hot w; was obtd by pouring 5-amino-3-carboxy-phenyloxamic acid into excess HCl, diazotizing with $NaNO_2$, converting into the perbromide, treating with $NH_3$ and adding HCl to ppt the product. This compd, when boiled with dil KOH, is decompd into oxalic acid & *5-azido-3-aminobenzoic acid,* $[H_2N.C_6H_3(N_3).COOH]$, sl reddish ndls (from w) which detonate when heated(Ref 1 & 2)
*Refs:* 1)Beil **14**, 418 2)P.Griess, Ber **21**, 1562 (1888) & JCS **54III**, 826-7(1888)
*Note:* No nitrated derivs were found in Beil

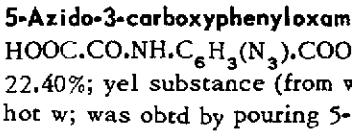
**(5'-Carboxypyrido)-1',2':4,5-tetrozole**; 6-Carboxy-pyridotetrazole (Benson); or Tetrazolo[$\alpha$]-pyridinecarboxylic Acid (Richter-Anschütz) [called 1.2.3-Triaza-indolizin-carbonsäure-(6) in Ger],



; mw 164.12, N 34.14%; col ndls (from w), expl on heating above 338°; sol in hot w; was prepd by treating an aq soln of the hydrochloride of 5-carboxy-2-hydrazinopyridine with K nitrite. This compd, on oxidation with alk permanganate soln, yields unstable tetrazoles.

It forms salts and some derivs which are expl: *Silver salt,* $AgC_6H_3N_4O_2$, crysts, deflgr on heating (Refs 1,2 & 3) and *(5'Carbonylazido-pyridine)-1',2':4,5-tetrazole,* $N_3.OC.C_5H_3N_4$; mw 189.14, N 51.84%; crysts (from alc), mp 103-4°, expl on heating in a flame; sl sol in cold alc or hot w; was prepd by treating an aq soln of the hydrochloride of 5-carboxy-hydrazide-2-hydrazinopyridine with $NaNO_2$ (Refs 1 & 2)
*Refs:* 1)Beil **26**, 564 2)W.Markwald & K.Rudzik, Ber **36**, 1111, 1115-16(1903) 3) V.vonRichter & R.Anschütz, "The Chemistry of the Carbon Compounds", vol 4, The Heterocyclic Compounds and Organic Free Radicals, Elsevier, NY(1947), 214 4)F.R.Benson, ChemRevs **41**, 19(1947)

**(3'-Carboxypyrido)-5',6':4,5-vic(or 1,2,3)-triazole** {called [Pyridino-2'.3':4.5-triazol]-carbonsäure-(5'); or 5.6-Azimino-nicotinsäure in Ger},

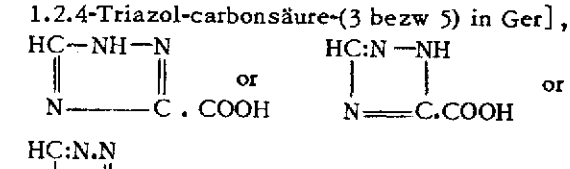


; mw 164.12, N 34.14%; crysts + $H_2O$ (from w), mp becomes anhyd at 150°, dec ca 270°; sol in hot alc or hot w; sl sol in cold alc or cold w; was prepd by treating a HCl soln of 5,6-diaminopyridine-carboxylic acid with $NaNO_2$

It forms salts, some of which are expl: *Ammonium salt,* $NH_4.C_6H_3N_4O_2$, crysts, defr on heating; *Barium salt,* $BaC_6H_3N_4O_2$, crysts, expl on heating; *Copper salt,* blue amor solid, expl on heating; *Lead salt,* wh crysts, expl on heating; and *Silver Salt,* $Ag_2C_6H_2N_4O_2$, amor solid, expl on heating(Refs 1 & 2)
*Refs:* 1)Beil **26**, 564 2)W.Markwald, Ber **27**, 1337-39 (1894)

### Carboxytriazole and Derivatives

**3-Carboxy-$\alpha$-sym(or 1,2,4)-triazole** [called 1.2.4-Triazol-carbonsäure-(3 bezw 5) in Ger],

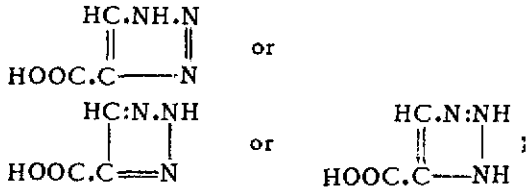


; mw 113.08, N 37.16%; crysts, mp 137° (dec), begins to decomp at 80°; almost

insol in alc or w; was prepd from 3-methyl-asym -triazole by oxidn with $KMnO_4$ soln. It decomp, on heating or by boiling water, into asym -triazole (Refs 1,2 & 3). It forms a *Copper salt*, $Cu(C_3H_2N_3O_2)_2$, yel-grn cryst powd which is mildly expl

*Refs:* 1)Beil **26**, 280-1 2)A.Andreocci, Ber **25**, 225-30(1892) 3)J.A.Bladin, Ber **25**, 744(1892)

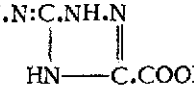
**4-Carboxy-α-vic(or 1,2,3)-triazole** [called 1.2.3 -Triazol-carbonsäure-(4 bezw 5) in Ger],



mw 113.08, N 37.16%; lfts (from concd HCl) or cryst solid (from w), mp 211-20° (dec, depending upon conditions of heating); readily sol in hot w; sl sol in cold w or alc; almost insol in eth, chlf or AcOH; was first prepd from 2-aminophenyl-vic-triazole carboxylic acid with $KMnO_4$ in aq NaOH (Refs 1 & 2). Other methods of prepn are given in Refs 1,3,4 & 5. On heating above the mp, it yeilds vic-triazole. Its *Silver salt* explodes on heating (Ref 2)

*Refs:* 1)Beil **26**, 277 2)O.Baltzer & H.vonPechmann, Ann **262**, 317-20(1891) 3)T.Zincke, Ann **311**, 317(1900) 4)O.Dimroth, Ber **25**, 1044(1902) 5) A.Peratoner & E.Azzarello, AttiAccadLinceiRend [5] **16**II, 320(1907) & JCS **92**I, 980(1907)

**5-Nitrosamino-3-carboxy-α-sym-triazole** [called 5-Nitrosimino-1.2.4-triazolin-carbonsäure-(3); 5 -Nitrosamino-1.2.4-triazol-carbonsäure-(3); or 5 -Diazo-1.2.4-triazol-carbonsäure-(3) in Ger],

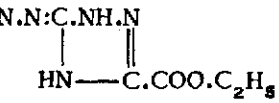


and other desmotropic forms. This compd is described in Vol I of this Encyclopedia as *5-Nitrosamino-α-sym-triazole -3-carboxylic Acid* under Aminotriazolecarboxylic Acids and Derivatives, p A270-R

It was patented in France as a constituent of priming mixts: 5-Nitrosamino-3-carboxy-α-sym -triazole 1-10, LSt 30-60%, and the remainder $Sb_2S_3$, $PbO_2$, $Ba(NO_3)_2$ & CaSi(Ref 2)

*Refs:* 1)See Vol I,p A270-R 2)Deutsche Waffen- u Munitionsfrabriken AG, FrP 824130(1938) & CA **32**, 5630(1938)

**5-Nitrosamino-3-carboxy-α-sym-triazole Ethyl Ester,**



and other desmotropic forms; mw 185.15, N 37.83%; solid substance, mp explodes on heating or by friction; was prepd by treating the ethyl ester of 5-amino-3-carboxy-α-sym-triazole with aq $NaNO_2$ + HCl, under cooling (Refs 1 & 2). The ester is a more powerful expl than its acid

*Refs:* 1)Beil **26**, 311 2)W.Manchot & R.Noll, Ann **343**, 8-9(1905)

**Carburant**(Fr). Combustible fuel for engines or rocket motors

**Cardox.** It is a blasting device first introduced ca 1920 in the coal mines of US and approved in 1928 by the Bur Mines for use in gaseous and dusty coal mines. Essentially, Cardox is a heavy-walled steel cylinder (cartridge) contg at its lower end a hole which is covered hermetically with a thick steel diaphram(release disc). Its upper, open end is covered with a detachable head contg an electric firing device(igniter) and a heating element consisting of a mixt of an oxidizer and fuels. For example the Brit Cardox described in Ref 5, contains: K perchlorate 85, kerosene 8.5, o-MNT 4.5, castor oil 0.5 & asbestos fibers 1.5%. After filling the cartridge with liq (or solid) carbon dioxide, the ensemble is placed in the borehole(drilled into coal) and tamped. On passing an elec current thru the igniter, the combustibles of heating element are ignited and the heat generated is sufficient to convert $CO_2$ to a gas at a pressure of the order of 30000psi. This causes rupture of the steel diaphragm, thus permitting the gas to escape with great force and rupture the seams surrounding the borehole

Cardox is flameless, non-brisant and evolves no toxic gases. It breaks coal into fairly large pieces(Refs 1-6)

Addnl Refs list various modifications of blasting cartridges using liq or solid carbon dioxide;and in Vol I,p A117 is briefly described the device called "Airdox" which uses compressed air in lieu of $CO_2$ (See also Ref 5,pp 137-42)

Another flameless blasting cartridge is known as "Hydrox" (Ref 5,pp 127-33)

*Refs:* 1)J.E.Tiffany, USBurMines RI **2920**(1929) (Description of "Cardox" cartridges) 2)Pepin Lehalleur(1935), 361 4)Thorpe **4**(1940), 562 3) Kirk & Othmer **3**(1949), 149 4)Ullmann **9**(1957),

775 5)Taylor & Gay(1958), 123-7 6)Cook(1958),16 *Addnl Refs:* a)D.Hodge, BritP 320226(1928) & CA **24**, 2606(1930); BritP 324617(1928) & CA **24**, 3904(1930); BritP's 328716 & 328717(1929); CA **24**, 5499(1930); BritP 329636(1929) & CA **24**, 6020(1930); BritP 332196(1929) & CA **25**, 208 (1931)(Blasting cartridges for use with compressed carbon dioxide) b)D.Hodge, BritP 348657(1929) & CA **26**, 849(1932)(Blasting cartridge contg $CO_2$ and heating element consisting of an elec igniter and mixt of K chlorate 68, Al 27 & paraffin 5%) c)G.S.Rice, USP 1751659(1930) & CA **24**, 2606 (1930)(Blasting cartridge contg $CO_2$) d)D.Hodge, & W.Eschbach, BritP 345284(1929) & CA **27**, 1177(1933)(Blasting cartridge contg $CO_2$, elec igniter, primary chge of $Pb(CNS)_2$ & $KClO_4$ and a secondary chge of Fe & $KMnO_4$) e)A.C.Scott & D.Hodge, BritP's 354305, 354306 & 354342(1930) & CA **27**, 2303(1933)(Blasting cartridges for use with $CO_2$ contg in their heating elements O -carrying salts, such as K chlorate or perchlorate and combustibles, such as phenolformaldehyde resin, nitrobenzene kerosene, castor oil, etc) f) A.Ignatieff, MiningMag **48**, 73(1933) & CA **27**, 2580(1933)(Description of principles and applications of Cardox cartridges) g)L'air Liquide, FrP 752086(1933) & CA **28**, 900(1934)(Liquefied or solified gases used as blasting chges in mines are rapidly evapd by a heating compn composed of inorganic oxidizers, such as K chlorate, and combustibles, such as paraffin) h)A.C.Scott, BritP 397203(1933) & CA **28**, 900(1934); USP 1957733(1934) & CA **28**, 4235(1934)(Blasting cartridge for use with compressed $CO_2$ or other inert gas contains a heating element comprising an O-carrying substance such as K perchlorate thru which a resinous material such as "Elo" resin is distributed) i)D.Hodge & A.Ignatieff, BritP 405645(1934) & CA **28**, 4602(1934)(Cartridge contg condensed gas, such as $CO_2$ and a heating element comprising a liq mixt of an oxidizer and a fuel) j)A.G.Suvorov, ZhPriklKhim **8**, 341-5(1935) & CA **29**, 6770(1935)(Cardox cartridge contg a heating element composed of K chlorate 90 & napththalene 10%) k)A.Ignatieff, BritP **32**, 6463 (1938) & CA **32**, 6463(1938)(Blasting cartridges contg compressed $CO_2$) l)L.D.Myers, USP 2145366(1939) & CA **33**, 3590-1(1939)(Blasting cartridges suitable for use with $CO_2$) m) C.L.Sandoe, USP 2207205(1940) & CA **34**, 8286 (1940)(Blasting cartridge suitable for use with $CO_2$ or with compressed air) n)A.Ignatieff, BritP 517417(1940) & CA **35**, 7195(1941)(A Cardox blasting cartridge) o)D.Ferrell & A.W.Helmholtz, USP 2253115(1941) & CA **35**, 8300(1941)(Mechanical blasting cartridge operated by gas pressure) p)G.N.Podbel'skii, Ugol' **23**, No 3, 12-13(1948) & CA **47**, 7769(1952)(Cardox cartridge contg in its heating elements a mixt of K chlorate and naphthalene)(Compare with Addnl Ref j)

**Carga hueca**(Span). Shaped Charge

**Carica a punta vuota**(Ital). Shaped Charge

**Carillon**(Explosive), patented in France in 1894, consisted of a hermetically closed vessel filled with mixt of hydrogen and oxygen produced on electrolytic decompn of water. The gas could be exploded by an elec igniter
*Ref:* Daniel(1902), 115

**Carlisle Lumber Co**, Onalaska, Washington, developed before WWII an explosive contg AN 85% activated carbon (from Douglas fir) 10 & flaked Al 5%, which was suggested as being of possible interest as a military expl. Its props were detd at PicArsn and found as follows: *Explosion Temperature* 281°(vs 290° for 80/20 Amatol); *Friction Pendualum Test* -negative; *Gap Test 2"*; *Hygroscopicity* -higher than Amatol; *Impact Sensitivity*, 2kg wt, BurMinesApp 87cm (vs 89 for Amatol); *Minimum Detonating Charge*(MF + Tetryl) >0.5g (vs 0.10g for Amatol); *Sand Test* 32g (vs 27.4g for Amatol or 38.2g for TNT); and *Thermal Stability* -less satisfactory than for Amatol

It was concluded that this material has no advantage over 80/20 -Amatol or other AN expls used for military purposes, such as for filling shells, bombs, land mines or as demolition charges
*Ref:* A.J.Phillips, PATR **1038**(1940)

**Carlit or Karitto.** A Japanese explosive, first used during WWII as a bursting chge for mines and depth chges, and in demolition chges primarily to conserve expls made from the limited supply of benzene and toluene. Its original compn was: Amm perchlorate 66, Si carbide 16, woodpulp 12 & petroleum 6%; grey pdr, nonhygroscopic, stable and safe to handle. It was believed that Si carbide aided in uniform propagation of the detonating wave thru the loosely packed pdr(Refs 1-3)

At present Carlit is used in Japan for industrial purposes and in some experimental solid rocket proplnts. Several modifications of

industrial Carlits, have been produced since WWII(Ref 3)(Compare with Type 98 Explosive, also known as Haensosan-bakuyaku)
*Refs:* 1)Anon, "Handbook of Japanese Explosive Ordnance", OPNAV **30-3M**(1945), 29 2)Anon, "Military Explosives", TM **9-1910** (1955), 212 3)R.P.Antonelli, OTIA, "Encyclopedia of Explosives", OrdnLiaison Group-Durham, NC(1960), 28-9

**Carlsonites.** Amm perchlorate expls patented, beginning 1898, by O.F.Carlson of Sweden

| Components | Designations | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| $NH_4ClO_4$ | 40-80 | 51-80 | 60-70 | 89 |
| Paraffin | – | 10-25 | 10-20 | – |
| Naphthalene | 5-8 | 20 | – | – |
| Charcoal | – | 5-20 | – | 11 |
| Petroleum | – | – | 10-20 | – |
| Woodmeal | 5-20 | – | – | – |
| "Ostalka"(residue from distn of petroleum) | 3-10 | – | 10-20 | – |

Accdg to Marshall (Ref 2), Carlsonites were the first Amm perchlorate expls submitted to HM Inspectors of Explosives. Some of the mixts were reported favorably, but no license was ever issued in the United Kingdom for these expls
*Refs:* 1)Daniel(1902), 116 2)Marshall, Dictionary(1920), 20 3)Giua, Trattato **6**(1959), 401

**Carnauba Wax.** See under Waxes

**Carnotite,** which is *Potassium Uranium Vanadate* contg Radium, was patented as an ingredient of pyrotechnic smoke-producing compns
*Ref:* J.DeMent, USP 2995226(1961), 23-4

**Carob-Bean or St John's Bread.** The pods of *Ceratonia siligua,* a Leguminosae, rich in sugar and gum. The gum, called *Carob-bean Gum,* used as an emulsifier in ice-cream, lozenge and toilet cream manuf (Ref 1), was proposed by Taylor (Ref 2) as a waterproofing coating agent for AN grains used in expl compns
*Refs:* 1)Hackh's(1944), 171 2)W.J.Taylor, USP 2654666(1953) & CA **48**, 3692(1954)

**Caro's Acid or Peroxymonosulfuric Acid,** $H_2SO_5$. A powerful oxidizing substance first obtained in 1898 by Caro on grinding K persulfate ($K_2S_2O_8$) with concd $H_2SO_4$, allowing to stand for an hour and then pouring on ice(Ref 1). Edwards (Ref 2) reported prepn by reacting chlorosulfonic acid ($HO.SO_2.Cl$) with 90% $H_2O_2$ at low temp. One sample stored overnight at 0° exploded when it was left for 10mins at RT. The cause has not been detd. In Ref 3 was reported a violent lab expln when some acetone was inadvertently added to a flask contg some of Caro's acid
*Refs:* 1)J.R.Partington, "A Textbook of Inorganic Chemistry", Macmillan, NY(1950), 487 2)J.O.Edwards, C & EN **33**, 3336(1955) & CA **49**, 14325(1955) 3)Anon, C & EN **38**, 59(Nov 21, 1960)

**Carpet Bombing.** See Bomb Carpet

**Car-Prill.** A blasting expl consisting of prilled AN ca 91.6%, ground walnut shells ca 4.6% & Diesel oil ca 3.8%. It belongs to the class of blasting agents called "Nitro-Carbo-Nitrates". It has been used in conjunction with dynamite (by loading each borehole with both materials) for blasting operations in strip-mining, open quarrying, construction of logging roads, etc

A devastating expln took place in the downtown section of Roseburg, Oregon at 1AM on Aug 7, 1959, when 4.5tons of "Car-Prill" and 2tons of dynamite were initiated by the intense heat from a nearby warehouse fire. This expl caused property damage of ca 9million, killed 9 and injured more than 125 persons
*Ref:* Anon, "The Roseburg, Oregon, Fire, Explosion and Conflagration", Report by the National Board of Fire Underwriters, New York **38**(1959)

**Carriages and Mounts Testings** are described in OP(Ordnance Proof) Manual **30-60**(1957)

**Carrière**(Poudre de). An inexpensive blasting expl compn: Na nitrate 63, sulfur 16 & sawdust 21%
*Ref:* Daniel(1902), 116

**Carronade.** An iron cannon, designed by Gens Melville & Gascoigne, and manuf in the last quarter of the 18th century at Carron, Scotland. It was a short, large caliber piece resembling a mortar. It differed from guns and howitzers in having a hinge below instead of trunnions. It was used on ships and shore to throw heavy solid

shot at close quarters. The shot could also carry incendiary materials. Some of these cannons were used at the battle of Trafalgar (1805)(Refs 1, 2 & 3)

The Carronade was such a success that one of its designers (Gascoigne) was invited to Russia (1779) to establish cannon plants(Ref 2)
*Refs:* 1)"Webster's New Twentieth Century Dictionary, Unabridged", The Publishers Guild, NY(1947), 262 2)W.Y.Carman, "A History of Firearms, StMartin's Press, NY(1955), 49-50 3) Merriam-Webster's (1961), 343

**Carry-Over Effect.** Under certain conditions, the passage of a detonation wave across the interface of two different explosives may cause the first expl to "overdrive" the second expl such that its pressure & deton velocity are higher than normal for a certain distance until a steady state rate is reached. This phenomenon is called the "carry -over effect" and is discussed in detail by Pike & Weir (Ref 6). It is related to detonation by influence previously described by several investigators (Refs 1 to 5)

For more info on this subject see Refs
*Refs:* 1)R.Brinkley & E.B.Wilson, OSRD **1707** (1943) 2)B.L.Hicks et al, JApplPhys **18,** 891 (1947) 3)K.P.Staniukovich, DoklAkadN **55,** 311 (1947) 4)H.Eyring et al, ChemRevs **45,** 69-181 (1949) 5)H.Jones, ProcRoySoc **204,** 9-12(1950 6) H.H.Pike & R.E.Weir, "The Passage of a Detonation Wave Across the Interface Between Two Explosives", ARE(Armament Research Establishment) Report **No 22/50,** British Ministry of Supply(1950)(Conf)

**Cartouche**(Fr). Cartridge; round (of ammo); canister (of a gas mask)

**Cartouche à balle**(Fr). Ball cartridge

**Cartouche à blanc**(Fr). Blank cartridge

**Cartouche complète**(Fr). Round of fixed ammunition

**Cartouche d'amorçage**(Fr). Ignition cartridge; primer

**Cartouche d'exercise**(Fr). Drill (or dummy) cartridge

**Cartouche sans douille**(Fr). Caseless cartridge or Cartridge without case. See under Cartridges

**Cartoucherie**(Fr). Cartridge factory

## CARTRIDGES

**Cartridge,** in a general, consists of an elongated container (called case, shell or wrapper), holding a specific item(s) in a fixed position. The item(s) which is in the case is complete in itself and it can be either removed for use outside the container or can be used without removal. Cartridge cases (qv) filled with proplnts are known as "cartridges, ammunition" and as "cartridges for cartridge actuated devices" and those which are filled with expls (such as dynamites) are known as "cartridges, blasting" (See also Cartridge Cases)
*Refs:* 1)Glossary of Ord(1959), 57 & 61 2) Merriam-Webster's(1961), 344

**Cartridges and Cartridge-Actuated Devices(CAD's),** called **Propellant Actuated Devices(PAD's)** by US Ordnance Corps. Cartridges used in these devices are called: *Power Cartridges* (US Navy) and *Gas-Generating, Power-Generating, Gas -Producing or Power-Gas Generating Cartridges* (literature). A cartridge-actuated device may be defined as a mechanism utilizing pressure supplied by gases evolved on deflagration of a propellant(fired mechanically or electrically in a special cartridge) to accomplish or initiate a mechanical action other than expelling a projectile
*Historical.* Although the first of these devices was invented comparatively recently (see Refs 1, 2 & 3), many types are now known and their use is very great especially in avation. One of the most important uses of CAD's is for catapults ejecting pilots and other personnel from rapidly travelling airplanes in cases of emergency

Prior to WWII when the speeds of military planes were not very high(up to 400mph) it was possible to escape from a disabled plane by jumping out. As speeds increased it became more difficult to separate from the plane by using muscular efforts, because much quicker action was required. It was found in Germany shortly before WWII that quick escape could be achieved by ejecting the seat with its occupant by utilizing the pressure of gases developed on firing a chge of proplnt in a specially designed cartridge. This cartridge was named "Schleudersitzpatrone"(Ref 6). Many Ger fighter plane were eventually equipped during WWII with seat-ejecting devices. The British started in 1945 to add such devices to all fighter planes with speeds greater than 400mph. In the

US, although, the study of the emergency escape began as early as 1940, it was not until 1947 that the first ejection seat catapult was standardized. It was designated "MI Personnel Catapult". This was followed by design and development *of "M1 and M2 canopy removers"* or simply *removers*. All of these devices were mechanically iniated. As this method of initation was not very satisfactory, aninitiationutilizing a propInt gas pressure source was developed in 1949 at Frankford Arsn, Philadelphia, Pa. At the same time the catapult was redesigned to incorporate the new "initiator"

With the advent of the B-52 plane and its requirements for multi-crew, multi-function, integrated escape systems, there was developed (ca 1951)a device which could furnish thrust to position ejection seats and to unlock hatches. This device became known as *thruster* and since 1951 several models have been developed(Ref 14, pp 1-2)

The CAD's (or PAD's) described in Ref 14 are arbitrarily divided into the following three categories:

*A)Gas-Generating Devices.* They may be subdivided into "short duration" and "long duration". The first, called *initiators*, are designed primarily to supply gas pressure (during usually less than 1sec) to operate the firing mechanisms for devices such as catapults. They also may serve as sources of energy for operating piston devices such as *safety-belt releases* and *safety-pin extractors*. For systems where several CAD's are fired in sequence, initiators may contain a "combination train element"(delay element) to delay propInt ignition for a specific time to permit completion of another operation. The "long duration" devices, also called "gas-generators" may supply pressure of gas for as long as several mins. Their principal uses are to spin the gas turbines, to operate pumps or to operate various missile controls(Ref 14,pp 3-5 & 17)(See also Ref 11,pp 56-61, 67-83 & 95)

*B)Stroking Devices.* They may be subdivided into "open" and "closed" CAD's. In the first type (such as in *catapults* and *removers)*, there is separation of piston from cylinder, accompanied by escape of propInt gases(See illustration on p 6 of Ref 14). In the "closed" types(such as used in *thrusters* and *ejectors*), the piston does not separate from the cylinder and the gas does not escape into atmosphere,but may be bypassed to other CAD's. Function of catapult remover and thruster were briefly discussed above, under Historical. For more info on catapults, see Ref 11,pp 12-21, 39-42 & 62-4 and Ref 14,pp 6-7; for removers (canopy removers), See Ref 11,pp 10-11 & 56-61 and Ref 14,p 8; and for thrusters, see Ref 11,pp 83-7 & 97 and Ref 14,p 8. The *ejector* usually serves to eject small masses, such as parachutes(See also Ref 14,pp 8-9 & 146)

*C)Special Purpose Devices.* Included in this category are: *cutters*(such as for severing cables and reefing lines of parachutes)(Ref 11,pp 5-9 & Ref 14,p 9); *releases*(for disconnecting the parachute from a crash-locator beacon, for suspending and releasingsingle lug bombs, for pulling safety pins from other CAD's, etc)(Ref 14,p 10); *exactors*(gas-operated firing pin release mechanisms used in aircraft jettison systems) (Ref 11,pp 64-6 & 94); *electric ignition elements* (devices designated to replace the firing pins and percussion primers used with gas or mechanically fired CAD's (Ref 14,pp 10-11)

In Ref 14,pp 2-4 are mentioned the following other applications of CAD's: ejection of radio beacons in the event of a crash, supplying gas pressure to operate hydraulic pumps in missiles, releasing bombs and jettisoning stores from aircraft, ramming of heavy projectiles into the breech of howitzers, starting Gatling gun rotators and as gas generators for temporarily pressurizing hydraulic, air or fuel lines in the event of prime equipment failure

In Ref 11 are described the following additional devices:

*butterfly valve cartridge*(used to automatically close the butterfly steam valve on a runaway shot preventer device of a steam catapult system in an aircraft carrier (Ref 11,pp 3-5 and Ref 12,p 57); *fire extinguisher cartridges*(used to release fire extinguishing fluid into the area surrounding a jet AC engine on fire (Ref 11,pp 22-7); *jet engine igniter cartridge*(used for relighting a jet engine, when the normal air starting ignition system fails during flight)(Ref 11,pp 27-30); *lap belt release cartridges*(used to activate automatic release lap belt after a delay of 3/4 or 2secs from the time the seat and occupant have been ejected from a plane in emergency escape)(Ref 11, pp 30-5); *cartridge-vial, life raft*(used to actuate automatic equipment of a life raft in an emergency ditching at sea; it consists of a cartridge assembled to a vial of compressed carbon dioxide; immersion of device in sea water initiates an elec current which activates an elec squib thereby releasing the $CO_2$ for inflating the

raft(Ref 11,pp 35-8 and Ref 12,p 61); *drogue gun cartridge*(designed to fire a small parachute, called "drogue", for stabilizing the flight of seat and occupant after they are ejected from a plane; this device is part of the Martin-Baker escape system)(Ref 11,pp 43-6 & 94); *parachute harness release cartridge*(used to actuate the release after delay of 3/4sec from the time of ejection from a plane)(Ref 11,pp 46-8); and *parachute opener cartridge*(used to open parachute 2secs after ejection)(Ref 11,pp 48-50); another cartridge releases the parachute 3secs after ejection(Ref 11,pp 51-3)

In Ref 13 are described various "power" cartridges and igniters used by the US Navy. The so-called *delay cartridges* are generally used to provide a predetermined time delay to actuate a release mechanism. The two types described in Ref 13 are used for releasing lap belts in airplanes

Charges used in cartridges for CAD's are either single- or double-base proplnts. For weaker impetus a BkPdr, based either on K or Na nitrate, may be used; and for very high impetus a composite proplnt(such as based on Amm perchlorate) may be used (Ref 13)

*Refs:* 1)ICI of Australia & New Zealand, AustralianP 100512(1937) & CA **31**, 5166(1937) (Gas-producing nondetonating charges for use in piston-operated mechanisms and in blasting) 2) J.M.Holm, USP 2090608(1937) & CA **31**, 6940 (1937)(Cartridge contg gas-generating materials, suitable for operating lifting jacks, fire extinguishers, etc) 3)R.A.Coffman, BritP 481639(1938) & CA **32**, 6446(1939)(Self -cumbustible fuel chges for engine starters) 4) R.A.Coffman, USP 2299464, -65 & -66(1942) & CA **37**, 1849(1943)(Power-generating cartridges used for starting engines) 5)C.D.Pratt, USP 2309978(1943) & CA **37**, 4230(1943)(Cartridges used for starting motors, closing switches, etc) 6)E.R.vonHerz, Jr, Explosivst **1954**, 64-8 & 92-8; CA **48**, 14210(1954) [Description of development of gas-generating cartridges (Gasdruckpatronen) in Germany before and during WWII. These cartridges were used for starting airplane engines (Starterpatronen) and for ejecting pilots and seats from airplanes (Schleudersitzpatronen)] 7)Frankford Arsenal, Philadelphia, Series of Progress Reports on Development of Cartridge Actuated Devices and Initiators, beginning in 1954(available at PicArsn) 8)F.W.Jarvis & ICILtd, GerP 949726(1956) & CA **53**, 18488(1959)(Power-gas cartridges) 9)Anon, "Ammunition General", TM **9-1900** (1956), 299-304(Cartridge-actuated devices for aircraft use) 10)F.W.Jarvis & T.B.Rhodes, GerP 1016171(1957) & CA **54**, 23334(1960)(Chges for power-gas cartridges. Eg:NG 43.9, NC 27.8, diethyldiphenyl urea 0.9, cellulose diacetate 26.3, K nitrate 0.9 & petrolatum 0.2%. Rate of burning 5mm/sec) 11)Anon,"Cartridges and Cartridge Actuated Devices", Bureau of Ordnance Pamphlet **2606** US Navy(1959)(Illustrations and descriptions for more than 30 types of devices, used by the US Navy) 12)Glossary of Ord (1959), 57-61 13)Anon, "Power Cartridges Handbook", US Naval Proving Ground, Dahlgren, Virginia(1961)(Illustrations and some data for numerous types of US Navy's cartridges and igniters) 14)Anon, "Ordnance Engineering Design Handbook, Propellant Actuated Devices", Ordnance Corps Pamphlet, ORDP **20-270**, OEHO, Duke University, Durham, NC(1961)(Comprehensive description of principal devices used by the US Air Force, including some design techniques) 15)Anon, "Small-Arms Ammunition", TM **9-1305-200**(1961), 53-4 (Cartridge, caliber .45, line-throwing) 16)US Military Specifications on various cartridges (See also Ref 11): a)MIL-C -25918(1)(CAD's for AC crew emergency escape) b)MIL-C-21234(1), MIL-C-21496A, MIL-C-22648, MIL-C-22652, MIL-C-22656 & MIL-C-22657 (Cartridge actuators) c)MIL-C-46221, MIL-C -46237, MIL-C-46241 & MIL-C-46271 (Cartridge for AC ejection seat catapult) d) MIL-C-25128(2)(Cartridge, starter, AC engine) e)MIL-C-45408, MIL-C-46200, MIL-C-46240 & MIL-C-46274(Cartridge, thruster) e)MIL-C -18653A,MIL-C-27002B,MIL-C-27019A & MIL-C -27029(Cartridge, bomb ejection) f)MIL-C -22244(Cartridge, cable cutter) g)MIL-C-10013 & MIL-C-12779A(Cartridge, line-throwing) h) MIL-C-22362(Cartridge impulse) i)MIL-C -13230A(Cartridge, cluster ejection) j)MIL-C -25641(Cartridge, gas generating, solid proplnt, AC & missile, secondary power systems)

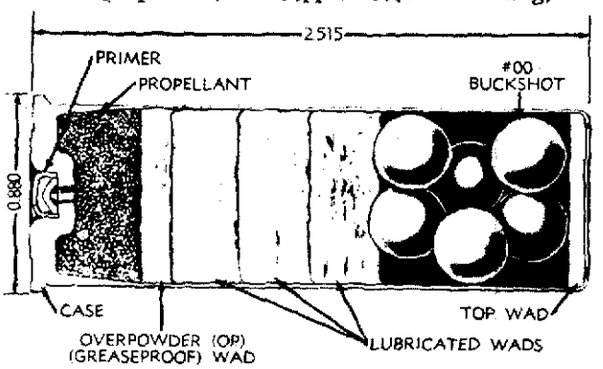
**Cartridge, Aircraft Canopy Remover.** See under Cartridge-Actuated Devices

**Cartridge, Aircraft Ejection Seat Catapult.** See under Cartridge-Actuated Devices

**Cartridge, Airdox.** See Airdox in Vol 1,p A117-R

**Cartridge, Aluminum or Aluminum Alloys.** See Refs 2,3,4 & 7 under Cartridge Cases

**CARTRIDGE, AMMUNITION** [Patrone(Ger) -cartridge for small arms or fixed artillery ammo; Kartusche(Ger)-cartridge or bag for separate -loading ammo; Cartouche(Fr)-generally for all types of ammo; Gargousse(Fr)-for separate loading ammo; Patron(Rus)-for all types of ammo; Oroodiinyi Parton(Rus)-cannon cartridge; Cartoccio(Ital) and Cartucho(Span)]. Cartridge, used in present smooth-bore firearms (shotguns) consists of a cylindrical pasteboard container (case or shell) with a metal (generally brass) base provided centrally with a priming cap. The case is partly filled with proplnt which is covered with cardboard or felt wads. This is followed with a load of lead shot and a closing wad. The ensemble is called "shotgun cartridge". These cartridges are used for combat, guard and survival purposes (Ref 15,pp 62-5)(See also Fig)




**US 12-Gage Shotgun Cartridge**

The term "cartridge" used in present military rifled, breechloading firearms is equivalent to the "complete round of ammunition" (See Vol 1,p A385-L of Encyclopedia). The present military cartridge consists of a cylindrical or bottlenecked metal (brass, or copper, gilding metal, aluminum or steel) container(case or shell) closed at one end and nearly filled with a chge of proplnt. A primer is inserted in the perforation of the closed end(base) of the case and a projectile(bullet or shell) may be crimped or force-fitted into the open end(neck) of the case

The purpose of a cartridge case(especially when used in recoil-type cannons) is not only to serve as a container for proplnt, primer and projectile, but also to prevent the escape of gas from the rear of weapon on firing the proplnt. This function of cartridge as "obturator" is due to the expansion of the case against the chamber wall under the pressure of burning proplnt(Ref 10,p 128)

*Historical.* In ancient firearms(which were smooth -bore, muzzle-loaders), no cartridges were used, but proplnt(BkPdr) was introduced loose thru the muzzle of the barrel and the wad and the balls rammed afterwards. In order to expedite loading of firearms while on horseback, a paper cartridge was invented. At first (ca 1550) it housed only the BkPdr chge, but later (ca 1590) cartridges contained the pdr and the balls. Gustavus Adolphus of Sweden(1594-1632) introduced the paper cartridge to his army at the beginning of the 17th century. This type of cartridge was not self-contained because it was not provided with a primer which was unknown at that time. The first self-contained cartridge was invented in 1826(FrP 3355) and an improved one in 1831 (EnglP 6196). LeFaucheux invented in 1836 the pin-fire cartridge made of cardboard and brass combination, something like present shotgun cartridge. Paper cartridges continued to be used until about 1850 or even later. The first really successful metallic cartridge, self-contained and reasonably moisture-proof, was patented in 1854 by Smith & Wesson. It was used in revolvers. The first metallic, center-fire cartridge was patented in 1858 by Morse and adopted in 1865 by the US Army. Foster patented, in 1860, the so-called "Burnside" cartridge which contained a grease chamber around the bullet. Williamson patented, in 1864, the so-called "Teat Cartridge"(Ref 13,p 7). The latter cartridge is not listed in Ref 2, but on p 44 the "Moore Tit Cartridge" is described

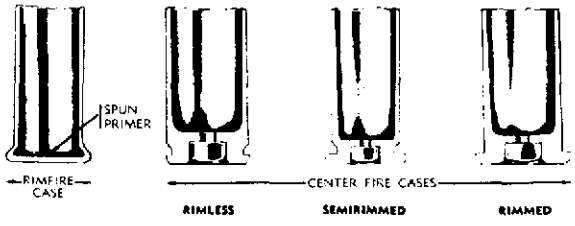
In 1866 Col(later Gen) Berdan, US Army, invented a cartridge with a special primer. His design was adopted by some European nations. In the same year Col Boxer, BritArmy, designed a different cartridge, known as "Boxer" cartridge. It was adopted for use in the Snider rifle and its "bottleneck" modification was used in the Martini-Henri rifle. Descriptions of both Berdan and Boxer cartridges are given in Ref 2,pp 45-8

After the invention of colloidal NC proplnt (1884) and of NC-NG proplnts (1887-8), calibers of small-arms cartridges were reduced and the bottleneck design was adopted for most of the rifle, carbine and machine-gun cartridges, leaving the cylindrical form for some grenade, small caliber rifles & carbines, revolver, and pistol cartridges(See Ref2,pp 21-154 and Ref 13,pp 1-17). Cartridges used in artillery ammo are cylindrical or slightly conical in form

I)**Cartridges, Military, US.** Based on usage, these cartriges may be subdivided into "small -arms cartridges" and "artillery cartridges"

*A)Small-Arms Cartridges (US)* are used in firearms caliber .60inch or smaller. Based upon type of

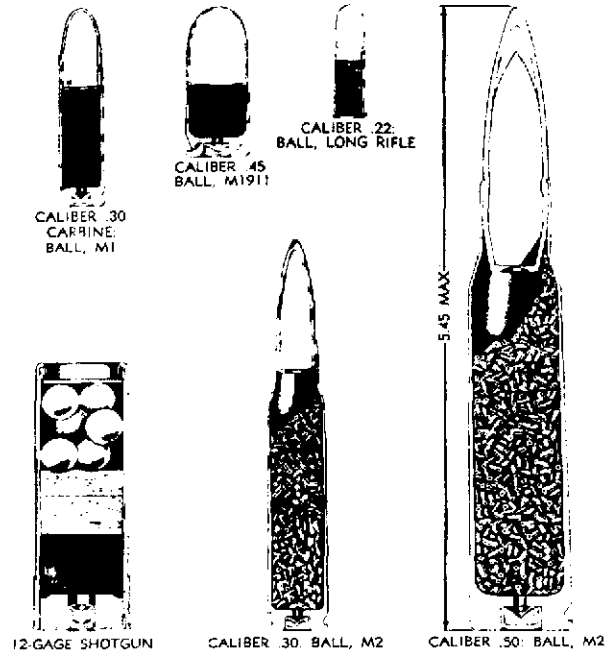
case, these cartridges may be classified as *center-fire* and *rimfire*. In a center-fire cartridge, the primer is located in a small well or pocket, in the center of the cartridge case head. The rimfire cartridge differs in that its priming mixt is located in the flat rim at the base of the cartridge cas. This rim also serves to properly locate the cartridge in the chamber of a firearm, and offers a means of extracting the cartridge case after firing. The caliber .22 cartridge(other than hornet) is the only current rimfire type used for military purposes(Ref 15,p 5)




**Types of US Cartridge Cases**

Center-fire cartridges may be classified as *rimless, semirimmed* and *rimmed*. Types of cartridge cases are illustrated in Fig

Illustration of a typical complete round of ammunition using a rimless, center-fire cartridge is given in Fig entitled "Typical Bullet & Cartridge Assembly", under BULLETS. See alsc illustration of components of US cartridges cals .22, .30, :45, .50 and 12-gage shotgun




**Components of Typical US Small-Arms Cartridges**

Depending upon its purpose, small-arms ctges are classified as *combat* or *service* and *noncombat* or *special*

The combat ctges are subdivided into:

a)*Armor-Piercing(AP).* See under BULLETS and in Ref 15,pp 5,41,44,54 & 56

b)*Armor-Piercing Incendiary(API).* See under BULLETS and in Ref 15,pp 5,42,54 & 56

c)*Armor-Piercing Incendiary-Tracer(APIT).* See under BULLETS and in Ref 15,pp 42,45,54 & 56

d)*Ball.* See under BULLETS and in Ref 15,pp 36-8,43,46,51,57,58 & 66-70

e)*Ball, Hornet.* See under BULLETS and in Ref 15,p 38

e)*Grenade.* A special blank ctge used in rifles assembled with launchers to project A/T, HE, fragmentation, illuminating, smoke & chemical, grenades, as well as ground signals(Ref 15,pp 50-1)(See also Fig)

g)*Incendiary.* See under BULLETS and in Ref 15,pp 44,58 & 60

h)*Shotgun.* See a brief definition and an illustration given at the beginning of this section and also in Ref 15,pp 44,58 & 60

i)*Spotter-Tracer.* See under Bullets, Spotter -Tracer and in Ref 15,p 60

j)*Tracer.* See under BULLETS and in Ref 15,pp 40,45,52 & 61

The noncombat ctges may be subdivided into:

a)*Blank.* See under Bullets, Blank and Dummy and in Ref 15,pp 39,45,53,62 & 69

b)*Dummy.* See under Bullets, Blank and Dummy and in Ref 15,pp 40,45,53 & 62

c)*Frangible.* See under Bullets, Frangible and in Ref 15,pp 46-7

d)*High-Pressure Test(HPT).* A ctge used for proof-firing of firearms. It is loaded with a quantity of proplnt sufficient to produce required high pressure which might vary from 1000 to 70000psi. The bullet consists of gilding metal or of other material(Ref 15,pp 41,46,53 & 62)

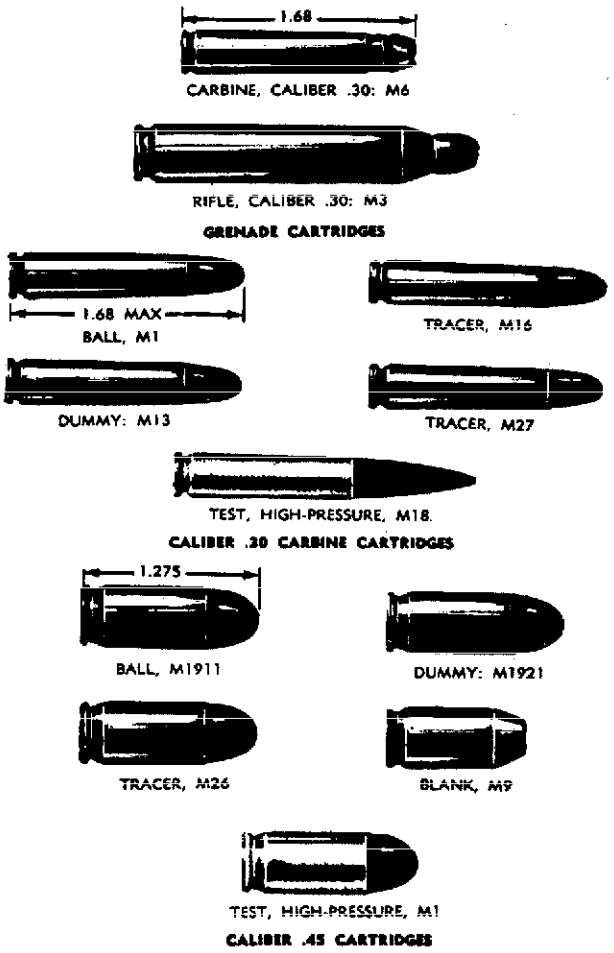
e)*Line-Throwing.* A ctge, cal 45-70 fitted with a non-corrosive primer and proplnt chge which is covered with one or more felt wads. It fires a 256-gram projectile attached to a std Navy line for a min distance 75yds at 30° elevation(Ref 15, pp 53-4)

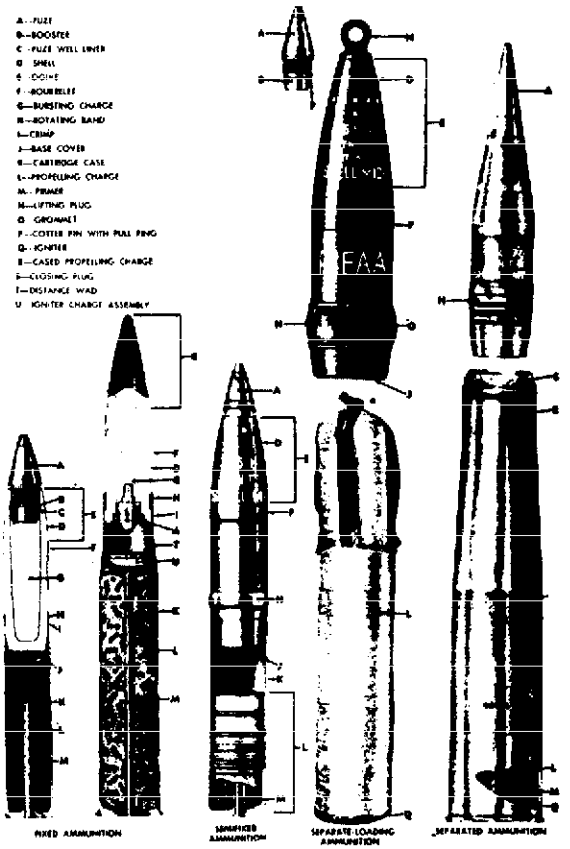
f)*Match.* A ctge used for target practice(Ref 15, pp 44 & 70)

g)*Practice.* A ctge listed in Ref 15,p 5 without description

h)*Shotgun, Blank.* See Ref 15,pp 64-5

B)*Artillery(Cannon)Cartridges(US)* are used in

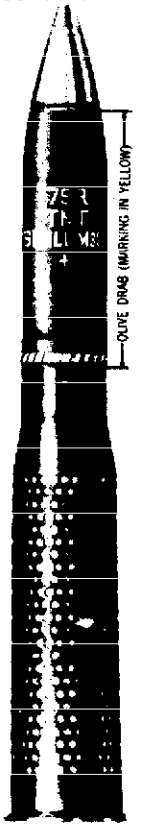



US Complete Rounds of Artillery Ammunition

weapons of calibers larger than 0.60inch. Calibers and type of ammo used previous to 1960 in cannons are listed in Vol 1,pp A385-L & A386-R of this Encyclopedia. To the three types of ammo: fixed, semifixed and separate-loading (listed in Encyclopedia and in Ref 7,pp 6-7), should be added the fourth type called *separated ammunition.* This consists of a primed brass or steel ctge case, a chge of proplnt(sealed with a closing plug made of asphalt, pressed paper board or plastic) and a projectile which is not attached by crimping. Following removal of shipping plug, the projectile and cartridge case are loaded into the cannon together, not separetely as in separate-loading ammo(Ref 7,p 6 & Ref 10, p 130). Having a nonadjustable proplnt chge, "separated" ammo may be considered a special type of "fixed" ammo(Ref 10,p 128), but accdg to Ref 4a,p 113, it is considered to be "separate loading". Illustrations of the four above types of ammo are given in Fig

An artillery cartridge case is usually made of a special type of brass or steel of spiral -wrapped multipieced or drawn construction. Its




Cartridge, HE for 75mm Recoilless Gun

form(usually cylindrical or slightly bottlenecked) and size conform to that of the chamber of the weapon in which the round is fired, except for recoilles weapons. The "head" of the case is relatively heavy in order to provide for firm attachment of a primer and a flange or groove to permit mechanical extraction. Cartridges used in automatic cannons have cases with an extracting groove instead of a flange or rim. The cartridge case in *recoilless* weapons is perforated in a manner to allow sufficient quantity of proplnt gases to escape into the weapon chamber and out of the breechblock into the atmosphere to counteract weapon recoil. The interior of recoilless-weapon cartridge cases contain a liner(of paper, rayon or plastic) that serves to cover the perforations, thus preventing the entrance of moisture and spilling of the proplnt grains(Ref 10 ,p 128)(See Fig bottom of p C 75)

Calibers of cartridges used ca 1950 in the US artillery ammo are listed in Ref 7

For larger caliber weapons, such as 155-mm guns and howitzers, proplnt charges are contained in bags(see under Cartridge Bags)

II)**Cartridges, Military, NATO, Small Arms.** The following types of North Atlantic Treaty Organization cartridges are described in Ref 15,pp 47-50:

7.62mm NATO, AP, M61; 7.62mm NATO, Ball, M59; 7.62mm NATO, Ball, M80; 7.62mm NATO, Test, High Pressure, M60; 7.62mm NATO, Tracer, M62; 7.62mm NATO, Blank, XM82 and 7.62mm NATO, Dummy, M63

No info at our disposal on cartridges used by NATO in artillery ammo, however a constant effort to standardize is being conducted(Ref 18)

III)**Cartridges, Military, Argentina.** Calibers of ammo used ca 1960 are lised in Vol 1,p A478-L of this Encyclopedia

IV)**Cartridges, Military, Belgium.** Calibers of ammo used ca 1961 are listed in Vol 2 of this Encyclopedia under Belgian Explosives, Ammunition, etc

V)**Cartridges, Military, France.** No info at our disposal.

VI)**Cartridges, Military, Germany.** Brief description of cartridges used during WWII are given in Ref 11. For more detailed info see TM **9-1985-3** (1953)

VII)**Cartridges, Military, Italy.** Descriptions of cartridges used during WWII are given in TM **9-1985-6**(1953)

VIII)**Cartridges, Military, Japan.** Descriptions of cartridges used during WWII are given in OPNAV **30-3M**(1945) and TM **9-1985-5**(1953)

No info at our disposal about cartridges used in other foreign countries

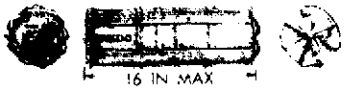
*Refs:* 1)Hayes(1938), 26, 376 & 658 2) M.M.Johnson Jr & C.T.Haven, "Ammunition", W.Morow, NY(1943), 21-68(Cartridge development from 1600 to the beginning of smokeless proplnt); 69-87(European military rifle cartridges from 1886 to 1943); 88-112(US military rifle & carbine cartridges from 1886 to 1943); 113-54(Smokeless proplnt sporting-rifle cartridges); 155-88(Pistol & revolver cartridges); 189-208(Shotgun cartridges or shells) and 371-4(Cartridge designations) 3) J.Newman, "The Tools of War", Doubleday, Doran & Co, NY(1943), 44-5 4)Anon, "Ammunition Inspection Guide", TM **9-1904** (1944), 180-220(Small-arms cartridges); 446-84 (Artillery cartridges) 4a)Anon, "Ammunition General", TM **9-1900** 1945),pp 111-15(See also Ref 10) 5)Ohart(1946),65,74 & 78-85(Small-arms cartridges); 171-83(Artillery cartridges) 6) G.M.Barnes, "Weapons of World War II", VanNostrand,NY(1947), 42-3(Small-arms cartridges) 52-3(Recoiless-guns cartridges) 7a)Anon, "Small-Arms Ammunition", TM **9-1990**(1947), 1-11 & 53-153 7)Anon, "Artillery Ammunition", TM **9-1901**(1950), 4-6, 69-160 & 174-201 7a)Anon, "Ammunition", US Military Academy, West Point, NY(1950), 3-8, 17, 26-7 & 31-46 8)Anon, "Fundamentals of Small Arms", TM **9-2205** (1952), 28-31 & 34 9)EncyclBritannica **1**(1952), 824(Artillery cartridges); **20**(1952), 810(Small -arms cartridges) 9a)PATR **2145**(1955),p Rus 2 (Ammunition)(Conf) 10)Anon, "Ammunition General", TM **9-1900**(1956) 81-94(Small-arms cartridges); 128-30(Artillery cartridges)(See also Ref 4a) 10a)ORDP 20-244(1957), "Artillery Ammunition", Secn 1 11)PATR **2510**(1958),pp Ger 25-7 & 177-80(Ger cartridges of WWII) 12) Glossary of Ord(1959), 57-61 13)H.C.Logan, "Cartridges, A Pictorial Digest of Small-Arms Ammunition", Stackpole, Harrisburg, Pa(1959) 14)W.H.B.Smith, "Small-Arms of the World", Stackpole, Harrisburg, Pa(1960), 699-703 15) Anon, "Small-Arms Ammunition", TM **9-1305-200** (1961), 2-10, 22-4 & 36-70 16)Anon, "Index of Specifications and Standards", Supplement Part 1, Alphabetical Listings, Armed Forces Supply Support Center, Washington 25, DC, Sept 1961,pp 107-11(US specifications for cartridge cases and cartridges for small-arms and artillery ammunition) 17)Anon, "Index of Technical Manuals, Technical Bulletins, etc", Dept of the Army Pamphlet No **310-4**, Washington 25, DC, April 1962,p 998

[Technical bulletins (TB's) describing cartridges calibers 40,75,81,90,105 & 280mm] 18)A.B. Schilling, Picatinny Arsenal;private communication (1962)

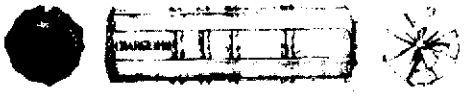
**Cartridge, Artillery.** See under CARTRIDGE, AMMUNITION

**Cartridge Bags.** Propellent charges in "separate -loading ammunition"(See Ref 7)(such as used in guns and howitzers caliber 155mm and higher) are contained in bags made of cloth which does not leave any residual smoldering fragments or ash in the bore after firing. Smoldering fragments might ignite unburned products resulting from combustion of the proplnt(mostly CO) causing a "flareback" (Ref 1,2,4 & 5).Silk cloth was used in the US before WWII, but when silk became unavailable (during the war) it was replaced by mohair. In Germany they used successfully cotton treated with a soln of NC. In GtBritain, Dreyfus(Ref 3) patented a cartridge cloth made of regenerated cellulose impregnated with guanidine or one of its salts, especially Gu metaphosphate

At present acrylic cotton fibers are used in US cartridge bags(Ref 6)(See also Fig)




CHARGE, PROPELLING M3 (GREEN BAG)




CHARGE, PROPELLING, M4A1 (WHITE BAG)

CHARGE, PROPELLING, M13

*Refs:* 1)Hayes(1938), 34-5 2)Anon, "Ammunition Inspection Guide", TM **9-1904**(1944), 507-10, 526-7 & 539-41 3)H.Dreyfus, BritP 569040(1945) & CA **41**, 4929(1947) 4)Ohart(1946), 184-91 5)Anon, "Artillery Ammunition", TM **9-1901**(1950), 337-52 6)Anon, "Ammunition General", TM **9-1900**(1956), 130-1

**Cartridge, Ball.** A cartridge in which the projectile is of the ball type(See also under BULLETS and CARTRIDGE, AMMUNITION)
*Ref:* Glossary of Ord(1959), 57

**Cartridge Belt.** A leather or fabric band with loops or pockets for carrying cartridges or cartridge clips. It can be worn around the waist like a belt or suspended from the shoulders. In the latter case it is called *bandoleer*
*Refs:* 1)Glossary of Ord(1959), 31 & 57 2) Merriam-Webster's(1961)

**Cartridge, Belt.** A fabric or metal band with loops for carrying cartridges that are fed from it into a machine gun or other automatic weapons
*Ref:* Glossary of Ord(1959), 57

**Cartridge, Blank.** An item consisting of a ctge case, primer and smokeless proplnt or BkPdr, but no projectile. It is used in training in signaling, and in saluting(See also under BULLETS and under CARTRIDGE AMMUNITION)
*Ref:* Glossary of Ord(1959), 57

**Cartridge, Blasting.** Blasting expls(such as dynamites) are usually furnished in cylindrical containers, called wrappers or shells consisting of paraffined paper. These not only serve to protect the expl from moisture, but they also facilitate handling, storage and loading into boreholes. The ensemble: ie container plus charge is called "cartridge". Cartridges manufd by the DuPont Co are subdivided into "small"(diam 1 1/8, 1 1/4, 1 1/2, 1 3/4 & 2" and length 8") and "large"(diam 4, 4½, 5 & 7" and length 16 or 24"). The largest cartridge which can be shipped under ICC(Interstate Commerce Commission) Regulations is 50lbs, total wt, with a max diam 12" & a max length 36"(except for dynamites contg less than 10% NG, in which case there is no limitation on length)

For dynamite cartridges having a diam of 2" or less, the most common type of container is made from spirally wound Manila paper which is impregnated with paraffin. For very hygroscopic expls, the container is dipped, after filling it with expl,into a bath of molten paraffin. For cartridges larger than 2" in diam, a spiral wound, glued paper shell is used. This type of cartridge is waterproofed by spraying with molten paraffin. Some powder-type dynamites are packed in strong Manila paper bags, making 12.5-lb chges. This type of loading facilitates the pouring of expls into small diam boreholes

For some types of blasting, BkPdr is still in use. The DuPont Co manufactures pressed cylindrical pellets ca 2" long and 1¼ to 2" in diam, provided with a central hole 3/8" in diam. Four

of these pellets are wrapped in red shell paper to form a cartridge 8" long. The cartridge is then dipped in paraffin

Some types of work, notably seismic prospecting, require a means of joining dynamite cartridges together to make a continuous column for loading into boreholes. The coupling devices are known as *cartridge couplers* and the type manufd by the DuPont Co is called "Fast-Coupler" (Ref 3,p 56)

It should be mentioned that after WWII, when large quantites of scrap, cast TNT were available as surplus material, some blasting cartridges for use in "strip mining" were made by filling cylindrical cardboard containers(3-4" in diam and ca 3ft long) with lumps of TNT. For initiation of TNT, a cartridge of dynamite provided with a blasting cap was inserted in the upper (open) part of each cardboard cylinder(Ref 6)

Compositions of expls used in blasting cartridges are given under Blasting Explosives

Some special cartridges, such as Airdox, Cardox, Chemecol, Hydrox and Sheathed Cartridges are described separately(See also Ref 5)

Cartridge-packing machines for dynamites are briefly described in Refs 1 & 2

*Refs:* 1)Naoúm,NG(1928), 167-73 2)Stettbacher (1933), 302, & 304-9 3)Blasters'Hdb(1952), 47, 54-7, 65, 70 & 79-82 4)A.Izzo, "Manuale del Minatore Esplosivista", Hoepli, Milano(1953) 5) Taylor & Gay(1958), 123-44 & 160 6)G.D.Clift, Chemical Center, Edgewood, Maryland;private communication(1962)

**Cartridge, Bomb Ejector.** See under Cartridge -Actuated Devices

**Cartridge, Butterfly Valve,** See under Cartridge -Actuated Devices

**Cartridge, Canister.** A ctge assembled with a canister(qv)

**Cartridge, Canopy Remover.** See under Cartridge -Actuated Devices

**Cartridge, Cardox.** See Cardox

**Cartridge Cases.** It has been mentioned under CARTRIDGE, AMMUNITION, that the case serves as a container for propints and also for sealing off the rear end of the gun tube, during firing, against the back pressure of propelling gases. More detailed description of functions of a cartridge case is given in Ref 36,p 231. Cartridge cases used in ammunition are usually cylindrical or bottlenecked in shape and can be of paper, cardboard, parchment, metal, cloth or combustible material. The most common material formerly used for cartridge cases for military purposes was brass(Refs 1,16 & 22 and some Refs, under CARTRIDGE, AMMUNITION)

As brass was a critical material during WWII, in Europe, the Germans started to use steel and many cases were manufd from this material(Ref 28a,p Ger 27). As steel proved to be a satisfactory material, steel cases are now made in other countries including US(Refs 8,9,10,11,13, 15,17,21,24a & 28). Other metals such as Al and its alloys(Refs 2,3,4 & 7) or Zn-Cu alloys(Ref 6) have also been tried. The possibility of using sintered iron cartridges has been investigated at Frankford Arsn, Philadelphia(Ref 20), but further work is required. Plastic cartridge cases are described in Refs 12 & 27

Illustrations of typical metallic cartridge cases are given under CARTRIDGE, AMMUNITION

Since metallic, artillery cartridge cases are expensive, they are usually recovered after firing and then shipped back for reprocessing or salvaging of the metal(Ref 36). A non-metallic cartridge case which would burn completely during firing of a weapon would be an advantage to all troops. Such a cartridge,now known as "combustible case", was first developed during WWII in Germany(Ref 25). The case was made from nitrated pulp. Combustible cases are also manufd in the US, but the compn of their wall material is either not revealed or classified (Refs 26,29,31,32,33,34, & 36). The so-called "cartridge without case" or "caseless cartridge", invented in France(Ref 24) does not seem to be promising

One disadvantage of a combustible case is that it does not perform the function of sealing off the rear end of the gun tube, which prevents leakage of the high-pressure propelling gases. This function is achieved in a cartridge case consisting of a short metal base to which is attached a combustible cylinder. This cartridge case is called "partially combustible"(Ref 36,pp 232 & 234)

*Refs:* 1)M.Soto, Memorial de Artileria(Feb & Aug 1930) [Translation from Span in MAF **12**, 219-46 (1933)] (Manuf of cartridge cases) 2) Aluminium Industrie AG, BritP 455761(1936) & CA **31**, 2578(1937)(Cartridge cases for military purposes made of Al-alloy which is coated with

oxide produced by anodic oxidation) 3) Schering-Kahlbaum AG, BritP 466320(1937) & CA **32**, 782(1938)(Ctge cases of Al or Al-alloy coated with $AlF_3$ or Al phosphate) 4)Aluminium Ind AG, BritP 473732(1937) & CA **32**, 2897-8(1938)(Cases from Al-alloy, being improved by heat treatment) 5)S.R.Carson, USP 2111167(1938) & CA **32**, 3618(1938)(Small-arms ctge cases are covered with a strongly adhering dry lubricating and protective coating such as a mixt of pyroxylin and very finely divided amorph graphite) 6)K.Staiger, USP 2190536(1940) & CA **34**, 4051(1940)(Ctge cases of Zn-Cu alloys) 7)J.Korpium, USP 2196018(1940) & **34**, 5045(1940)(Ctge cases of oxide-coated Al or Al-alloy) 8)H.R.Turner, IronAge **149**, No 12, 54-5(1942) & CA **36**, 3765(1942)(Artillery ctge cases made of steel) 9)C.D.Coxe, USP 2286064 (1942) & CA **36**, 6996(1942)(Ctge case manufd by a special process from low-carbon steel contg some Cu) 10)R.B.Schenk, IndHeating **10**, 639-40, 642, 644,646,648,650,652,654,656 & 658(1943) & CA **38**, 1197(1944)(A brief history of the development of steel ctge cases) 11)W.Hesse, Wehrtech-Monatsh **47**, 259-69(1943) & CA **39**, 4038(1945) (Development of Cu-plated steel ctge cases) 12) J.E.Rothrock, USP 2340695(1944) & CA **38**, 4448 (1944)(Ctge cases made of synthetic molding materials such as resin-lignin fiber mixt) 13) H.R.Turner, Metallurgia **29**, 281(1944) & CA **40**, 7126(1946)(Manuf of steel ctge cases carried out in 5 stages with several intermediate annealings) 14)A.M.Cohn, USP 2429548(1947) & CA **42**, 764(1948) [A ctge case shaped like a shotgun shell is coated on the inside with a flash compn (such as a mixt of aromatic nitrocompd and an oxidizer), and then loaded with grains(0.24" diam & 0.26" long) of colloided smokeless propInt. The flash compn causes uniform ignition thruout the entire ctge] 15)C.C.Fawcett et al, USP 2462851(1949) & CA **43**, 3770(1949)(Manuf of cases from carbon fine-grained steels by cup and draw-case forming techniques) 16)Encycl-Britannica **2**(1952), 787(Manuf of ctge cases) 17) K.T.Norris, Ordn **38**, 930-4(1954)(The steel ctge case) 18)W.N.King, Ordn **39**, 49-52(1954) (Manuf of steel ctge cases) 19)R.R.Gomez, Ordn **39**, 491-94(1954)(The spiral-wrapped case) 20)J.P.Scanlan, "Sintered Iron for Cartridge Cases", Frankford Arsn Rept No **R-1180**, Project TSI-46 (1954)(Attempts to fabricate cal .50 ctge cases from high density sintered iron cups by the cold drawing process gave rather promising results, but further work is required) 21)L.Schiller, Ordn **40**, 358-61(1955)(Comparison of heat-treating methods used in manuf of steel artillery ctge cases) 22)Papers presented at the Cartridge Case Committee Meeting, Held at NOL, White Oak, Md, Ordn **40**, 535-44(1955)(Discussions on various methods of manuf artillery ctge cases) 23)L.Pourquie, MAF **29**, 333-45(1955)(Théorie de fonctionnement des douilles au tir), translated by Dr G.Loehr as "Theory of the Functioning of Cartridge Cases During Firing", PicArsn Translation No 6(1956) 24)M.Linyer de la Barbée, MAF **29**, 801-16(1955)(Cartouches sans douilles), translated by Dr G.R.Loehr as "Cartridges Without Cases", PicArsnTranslation No 10(1957). Critical evaluation of the idea of "caseless cartridges" by Dr.H.Schmager is given on pp 16-2 [Linyer de la Barbée investigated the possibility of eliminating cartridge cases by directly combining propInt with projectile. He examined various possible solns and selected that of molding solventless propInts(of standard US accelerated combustion type) into a hollow multiperforated cylinder, which had an aperture at the forward end corresponding to the rear half of the projectile. This system has some advantages but its disadvantages are such that Dr.H.Schmager of Essen, Germany considers the idea as utopian] 24a)P.H.Burdett, Ordn **42**, 195-7(1957)(A review on the progress made in the development of steel ctge cases for small arms) 25)Drs H.Leuning, H.Walter & P.Müller, "Manufacture of Combustible Cartridge Cases from Nitrated Pulp", PicArsn Translation No 16 by Dr G.R.Loehr(1957) 26) S.Axelrod & G.Demitrack, PATR **2454**(1957) (Development of new formulations for combustible ctge cases)(Conf) 27)Anon, Ordn **42**, 474(1957) (Plastic ctge case) 28)Anon, Ordn **42**, 1029 (1958)(Steel spiral-wrap ctge case) 28a)PATR **2510**(1958),pp Ger 25-7(Ger cartridge cases) 29) S.Axelrod & V.Mirko, PATR **2478**(1958)(Improved formulations for combustible ctge cases)(Conf) 30)G.Demitrack, PATR **2522**(1958)(Combustible primer for use in combustible ctge case)(Conf) 31)S.Axelrod et al, Propulsion Application Section,Progress Report PAS Rept No **101**, PicArsn, (Feb 1960)(Research and development of combustible ctge cases)(Conf) 32)E.Wurzel, PAS Rept No **102**(March 1960)(A survey of methods of prepn of combustible ctge cases)(Conf) 33)Anon, C & EN **38**, 63(Dec 12, 1960)(A new combustible ctge case has been developed by Armor Research Foundation; compn is not given) 34)S.Axelrod et al,PAS Rept No **121**, PicArsn (July-Aug 1961)(Rept on progress of work on combustible ctge cases)(Conf) 35)US Military

Specifications: MIL-C-20367I, MIL-C-46236, MIL-C-46275 and MIL-C-46276 36)Gen W.K. Ghormley, Ordn **47**, 231-4(1962)(Combustible and partially combustible cartridge cases)

**Cartridge Cases, Tests of** are described in OP (Ordnance Proof) Manuals **8-16**(1942) and **10-50** (1957)

**Cartridge, Catapult.** See under Cartridge-Actuated Devices

**Cartridge, Center-Fire.** See under CARTRIDGE, AMMUNITION

**Cartridge, Chemecol.** See Chemecol

**Cartridge, Clip.** A sheet-metal item intended to hold together a number of cartridges at their bases in order to facilitate rapid loading into the magazine of a rifle or pistol
*Refs:* 1)Funk & Wagnalls, "New Standard Dictionary", NY (1958), 410 2)Glossary of Ord (1959), 72

**Cartridge Cloth.** See Cartridge Bags

**Cartridge, Combustible.** See Refs 25,26,29,30,31, 32,33 & 34 under Cartridge Case

**Cartridge Counts.** The number of dynamite cartridges, 1¼x8" contained in a 50lb box. This number is for "DuPont Gelatin" 85-96, for "Gelex" No1 110 and for "Doubel E" or "Monobel E" 205ctges
*Ref:* Blasters'Hdb(1952), 60,64 & 70

**Cartridge Couplers.** See under Cartridge,Blasting

**Cartridge, Cutter.** See under Cartridge-Actuated Devices

**Cartridge, Delay.** See under Cartridge-Actuated Devices

**Cartridge, Depth Charge Projector.** A ctge contg proplnt used to project a depth chge from a weapon such as a Y-gun, which is a two-barrel device, shaped like the letter Y. It throws depth chges to either side of the stern of a vessel on which the gun is mounted
*Ref:* Glossary of Ord(1959), 58 & 322

**Cartridge Diameter Effect on Strength and Sensitiveness of Explosives.** Tests conducted at the USBurMines with 40 and 60% gelatin- and ammonia- dynamites in ctges 7/8, 1 1/4 and 1 1/2" diam, showed that both the rate of deton and the gap test values decreased with a decrease in diam. It was found also that more misfires took place in small boreholes than in larger ones. As the proportion of paper wrapper to explosive itself is greater in smaller diam ctges, more poisonous gases such as CO are formed in boreholes. Both economy and safety are decreased by the use of 7/8" diam ctges and for these reasons they are not recommended for use. It is considered that the min diam should be 1¼"
*Ref:* S.P.Howell & J.E.Crawshaw, USBurMines Report of Investigation **RI 2436**(1922)

**Cartridge, Drogue Gun.** See under Cartridge Actuated Devices

**Cartridge, Dummy.** See under CARTRIDGE, AMMUNITION

**Cartridge, Ejection Seat Catapult.** See under Cartridge-Actuated Devices

**Cartridge, Engine Starter.** See under Cartridge -Actuated Devices

**Cartridge, Exactor.** See under Cartridge-Actuated Devices

**Cartridge, Full.** A ctge contg a chge of proplnt intended to produce full service velocity of a weapon
*Ref:* Glossary of Ord(1959), 58

**Cartridge, Gas-Generating.** See under Cartridge -Actuated Devices

**Cartridge, Grenade.** See Cartridge, Signal(for Grenade Launcher)

**Cartridge, Grenade(Rifle and Carbine).** See under CARTRIDGE, AMMUNITION and US Specification JAN-C-746

**Cartridge, High Pressure Test of.** See under CARTRIDGE, AMMUNITION

**Cartridge, Hydraulic.** A device consisting of a number of small hydraulic rams, used for disintegrating coal or rocks
*Ref:* Funk & Wagnalls, "New Standard

Dictionary", NY(1958), 410

**Cartridge, Hydrox.** See Hydrox Cartridge

**Cartridge, Igniter for.** See under Cartridge -Actuated Devices and "Power Cartridge Handbook", US Naval Proving Grounds, Dahlgren, Va(1959)

**Cartridge, Illuminating.** A pyrotechnic device used to provide illumination for reconnaisance, observation, bombardment, landing, and projectile firing. It usually contains a flare and a parachute for suspension in air
*Refs:* 1)Anon, "Military Pyrotechnics", TM **9-1981**(1951), 5 & 31 2)Glossary of Ord(1959), 155 3)US Military Specification MIL-C-12926A

**Cartridge, Incendiary.** A ctge contg a projectile designed to produce an incendiary effect at the target
*Refs:* 1)Glossary of Ord(1959), 59 2)US Military Spec MIL-C-1316(Cartridge, incendiary, caliber .50)

**Cartridge, Initiator.** See under Cartridge-Actuated Devices

**Cartridge, Jet Engine Igniter.** See under Cartridge -Actuated Devices

**Cartridge, Lap Belt Release.** See under Cartridge -Actuated Devices

**Cartridge, Life Raft Vial.** See under Cartridge -Actuated Devices

**Cartridge, Line Throwing.** See under Cartridge -Actuated Devices

**Cartridge, Paper.** See under CARTRIDGE, AMMUNITION

**Cartridge, Parachute Harness Release.** See under Cartridge-Actuated Devices

**Cartridge, Parachute Opener.** See under Cartridge -Actuated Devices

**Cartridge, Photoflash.** A device for use in connection with aerial photography at low altitudes 100 to 5000ft, during reconnaissance missions. It consists of a photoflash chge and delay fuze assembled in a case which, in turn is assembled in an electrically primed ctge case together with a small chge of proplnt
*Refs:* 1)Anon, "Military Pyrotechnics", TM **9-1981**(1951) 2)Glossary of Ord(1959), 60 3) US Specifications MIL-C-11232, MIL-C-11233A, MIL-C-12910 & MIL-C-13086

**Cartridge, Plastic.** See Refs 12 & 27 under Cartridge Case

**Cartridge, Pyrotechnic.** Any pyrotechnic item in the shape of a cylinder may be so called. This might include illuminating cartridges, such as flares(with or wo parachutes), photoflash, signals for pyrotechnic pistols and projectors, slick marker and smoke cartridges
*Refs:* 1)J.Goldenson & C.E.Danner, C & EN **26**, 1976-8(1948) & CA **42**, 6115-16(1948)(Description of some Ger, Ital & Japanese pyrotechnic cartridges used during WWII) 2)Anon, "Military Pyrotechnics", TM **9-1981**(1951), 5, 31-62, 72-6, 104-44 & 146-59 3)Anon, "Ammunition General", TM **9-1900**(1956), 193-212 4)US Military Specifications: MIL-C11232, MIL-C11233A, MIL-C-11765B, MIL-C-12825A, MIL-C-12910, MIL-C-12926A, MIL-C-13086, MIL-C-18539(2), MIL-C-45115 and MIL-C-46411

**Cartridge, Release (Aircraft Safety Lap Belt).** See under Cartridge-Actuated Devices

**Cartridge, Remover.** See under Cartridge-Actuated Devices

**Cartridge, Rimfire.** See under CARTRIDGE, AMMUNITION

**Cartridge, Sheathed.** See under Sheathed Cartridge

**Cartridge, Signal (for Grenade Launcher).** Some pyrotechnic ground signals are projected by means of grenade launchers attached to rifles or carbines, using special blank cartridges. The same method of propelling may be used for smoke rifle grenades
*Ref:* Anon, "Military Pyrotechnics", TM **9-1981** (1951), 111-22

**Cartridge, Sintered Iron.** See Ref 20, under Cartridge Cases

**Cartridge, Steel.** See Refs 8,9,10,11,15,17,21, 24a & 28, under Cartridge Cases

**"Cartridge Strength".** The term "strength"

refers to the energy content of an expl which in turn determines the force and power it develops and the work it is capable of doing. The strength of a straight NG dynamite is usually expressed in percent of NG by wt. The dynamite contg 40% NG is considered as a "standard" and its strength, as detd by ballistic mortar, serves for comparison with other dynamites. A dynamite contg 20% NG, when tested by ballistic mortar, does not give value of strength equal to 50% of 40% dynamite, but somewhat higher. This is because some of the 80% of other ingredients of 20% dynamite are also contributing to the energy delivered by the expl. When the percentage of NG is increased to 60%, it does not mean that its strength is increased 3-times as much as that of 20% dynamite. This is because the energy gained by increase of NG content, is partially lost due to the decrease in other ingredients, some of them contributing to the strength

It is often desirable to know how the strength of a single cartridge rates in comparison with the strength of a ctge of the same dimensions contg standard dynamite. This is known as "cartridge strength", "bulk strength" or "volume strength". It is detd by ballistic mortar tests

It should be pointed out, that two dynamites of the same strength do not necessarily produce the same blasting action in mines, quarries, etc. This is due to the fact that props other than strength, particularly density and velocity of detonation, have a distinct influence on their performance

*Refs:* 1)Blasters'Hdb(1949), 47 & 49 2)Blasters' Hdb(1952), 49

**Cartridge Tests.** For description of various tests to which cartridges are subjected for acceptance and, subsequently for surveillance and grading are described in:

*Refs:* Anon, "Test Methods for Small-Arms Ammunition", Ordnance Proof Manual ORD **M608-PM**, Frankford Arsenal, Philadelphia, Pa (1945) 2)Anon, "Small-Arms Ammunition", TM **9-1990**(1947), 40-50 3)Anon, "Artillery Ammunition", TM **9-1901**(1950) 4)Anon, "Arms and Ammunition Testing", Ordnance Proof Manual, OPM **10-50**, Vol 1(1957)

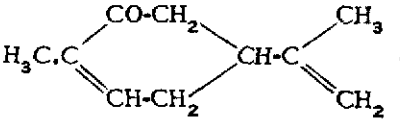
**Cartridge Thruster.** See under Cartridge-Actuated Devices

**Cartridge-Vial, Life Raft.** See under Cartridge -Actuated Devices

**Cartridge, Y Gun.** See Cartridge, Depth Charge Projector

**Cartridge, Zinc-Copper Alloy.** See Ref 6, under CARTRIDGE, AMMUNITION

**Carvone**( *1-Methyl-2-oxy-4-isopropylene-$\Delta^6$-tetra-hydro-benzene or 6,8-p-menthadien-2-one),*



; col liq, bp ca 225°; constituent of the oils of caraway, dill and cumin(Refs 1 & 4)

Harries et al(Refs 2 & 3) claimed to prepare the *diozonide* and the *diozonide peroxide* of carvone. Their structures were not detd. The diozonide was obtained as a yel oil on treating carvone in $CCl_4$ with ozone, followed by purification with petr ether. It deconpd on standing with formation of formaldehyde. Further treatment of diozonide with ozone yielded diozonide peroxide, which exploded by itself after standing for several hrs in a freezing mixt. It expld almost instantly when treated with warm w or when rubbed with a glass rod

*Refs:* 1)Beil **7**, 153, (101) & [128] 2)Beil **7**, (101) 3)C.D.Harries, "Untersuchungen über das Ozon", Springer, Berlin(1916), 445 & 450 3)Hackh's(1944), 173

**Case-Bonded Propellant.** A rocket proplnt charge prepd by casting directly in the chamber of rocket motor (See under CAST PROPELLANTS)

**Case, Cartridge.** See Cartridge Cases

**Cased Charges or Cased Explosives.** Any expl material confined in a case, which can be metal, plastic, cardboard, etc, may be so called. There is no book on this subject, but a number of reports, mostly of British origin. The confidential references listed below were not used as sources of info(Comp with Sheathed Explosives)

*Refs:* 1)GtBritAdvisoryCouncil, "Cased Charges, Casing of Different Materials, Mild Steel, Cast Iron, Lead and Aluminum", **AC 460**(1944)(Conf) 2)Anon, Safety in Mines Research Station, Buxton, England, "Cased Charges, Fragmentation", **D41**(1944), OTIA No **7149**(Conf) 3)G.Ward et al, "Evaluation of the Effectiveness of Various Types of Cased Explosives", Instrumentation Report **1134-57**, PicArsn(1957)(Conf)

**"Case Histories of Accidents in the Chemical Industry".** Title of the book published by the Manufacturing Chemists Assoc, Inc, Washington 9, DC, Vol 1(1962), 192pp

**Casein or Caseinogen.** A white phosphoprotein occurring as a colloidal suspension in milk. It can be pptd by heating milk with an acid or by other methods. Casein is the principal ingredient of cottage or other cheeses. It is also used in manuf of plastics, paints, paper, synthetic fibers, etc
*Refs:* 1)E.L.Tague, "Casein, Its Preparation, Chemistry and Technical Utilization", Van Nostrand, NY(1926) 2)Ullmann **3**(1929), 110-15 (not found in new edition) 3)Thorpe **2**(1938), 411-17 4)H.Hadert, "Casein and Its Uses", Translated from the Ger, ChemPubgCo, NY(1938) 5)E. Sutermeister & F.L.Browne, ' 'Casein and Its Industrial Application", ACS Monograph No 30, Reinhold, NY(1939) 6)Kirk & Othmer **3**(1949), 225-36 7)M.Beau, "La Caséine", Dunod, Paris (1952) 8)J.R.Spellacy, "Casein, Dried and Condensed Whey", Lithotype Process Co, San Francisco, Calif(1953) 9)US Military Specification, MIL-C-11532

**Casein, Nitration.** Accdg to Johnson & Kohmann(Ref 3), the first attempt to treat casein with nitric acid was made in 1885 by Nencki & Sieber(Ref 1) who obtd p-nitrobenzoic acid instead of nitrated casein, as expected. The 2nd attempt was made by von Fürth(Ref 2) who nitrated not only casein, but also white of egg (albumin) and horn
*Refs:* 1)M.Nencki & N.Sieber, Ber **18**, 394(1885) 2)O.von Fürth, ' 'Einwirkung von Sälpetersäure auf Eiweissstoff", Habilitationsschrift, Strassburg (1899)(Not available at PicArsn Library) 3) T.B.Johnson & E.F.Kohmann, JACS **37**,1864-5 (1915)

**Caseless Bomb.** Development of such bomb is discussed by A.L.Forchielli & J.H.Veltman in conf PATR **1855**(1951)

**Caseless Cartridge.** See Ref 24 under Cartridge Cases

**Casemate.** A fortified position or chamber (usually of concrete) in which ammunition can be stored and cannons or other weapons may be placed to fire thru embrasures. Also, an armored enclosure for a cannon or ammo on a warship
*Refs:* 1)EncyclBritannica **4**(1952), 961-2 2) Merriam-Webster's(1961), 346

**Case-Shot.** See Canister

**Casse-Blocs "Celtite".** A shaped-charge (charge creuse in Fr), consisting of AN 74.6 & 20/80-Pentolite 25.4%, manufd by the Société Anonyme d'Explosifs Industriels at Dijon, France. The chge is used by placing it directly on a rock, tree, etc
*Ref:* A.Izzo, "Manuale del Minatore Esplosivista", Hoepli, Milano(1953), 153 & 156

**Castan (Explosif de) or Poudre Végétale,** patented in 1884 consisted of K nitrate 48, K chlorate 20, S(flour) 20 & sawdust 12%
*Refs:* 1)Cundill(1889) in MP **5**, 305(1892) 2) Daniel(1902), 117 & 782

**Castan (Poudre Plate de).** BkPdr in the form of parallelipipedes measuring 10 x 10 x 2mm, formerly used in French cannons of calibers 75 & 85mm
*Ref:* Daniel(1902), 117

**Casteau(Explosifs de).** Safety expls patented in Belgium in 1899 and manufd by "La Poudrerie de Casteau". The No 1 formulation consisted of AN 90 & nitrodextrin 10%, whereas the No 2 variety contained 1 to 5% rosin added
*Ref:* Daniel(1902), 117

**Castellanos(Poudres).** Two types of dynamites were used at the end of the 19th century: a)NG+ NB + fibrous material + pulverized earth and b) NG + K or Na nitrate + picrate + sulfur + carbon + incombustible salt insol in NG(such as Zn, Mg or Ca silicate, Ca oxalate or Zn carbonate. The recommended compn of latter type consisted of : NG 40, K or Na nitrate 25, picrate 10, sulfur 5, carbon 10 & incombustible salt 10%
*Refs:* 1)Cundill(1889) in MP **5**, 305(1892) 2) Daniel(1902), 117-18

**Cast Composite Propellants for Rockets.** See under CAST PROPELLANTS

**Cast Double-Base Propellants for Rockets.** See under CAST PROPELLANTS

**Cast Explosives.** Expls melting at temps below 100° (such as TNT, mp ca 81°) and which are usually loaded in ammo by casting (see under

Loading of Ammunition). Expl mixts contg at least one of the low-melting components, in fairly large propn, can also be cast-loaded. In some countries, expls melting at higher than 100° were allowed to be cast. For example, PA(mp ca 122°) was cast-loaded by the Japanese in their "Shimose" shells

Following are US military expls which can be cast-loaded: Amatols(AN 60 or 50 & TNT 40 to 50%), Baratol(Ba nitrate 67 & TNT 33%), Baronal(Ba nitrate 50, TNT 35 & Al 15%) Composition B(RDX 60 & TNT 40% with 1% wax added), Cyclotols(RDX 75,70,65 or 60 & TNT 25, 30,35 or 40%), DBX(AN 21, RDX 21, TNT 40 & Al 18%), Ednatol(EDNA 55 & TNT 45%), Pentolit(PETN 50 & TNT 50%), Picratol(Amm picrate 52 & TNT 48%), Plumbatol(Pb nitrate 70 & TNT 30%), PTX-1 (RDX 30, Tetryl 50 & TNT 20%), PTX-2(RDX 44-41, PETN 26-28 & TNT 28-33%), Tetrytols(Tetryl 80,75,70 or 65 & TNT 20, 25, 30 or 35%), TNT, Torpex(RDX 42, TNT 40 & Al 18%); Trimonite(PA 88-90 & MNN 12-10%) and Tritonal (TNT 80 & Al 20%)
*Ref:* W.R.Tomlinson, Jr & O.E.Sheffield, "Properties of Explosives of Military Interest", PATR **1740**, Rev 1(1958)

**Cast Explosives of Winning.** Incorporation of a small quantity of a monobasic fatty acid(mp <100° and contg at least 8 carbon atoms, such as steraic acid) in expls contg TNT & inorganic nitrates, improves their flow props on casting and lessens the tendency of the chge to segregate. Eg: TNT 34, AN 34, Na nitrate 30, chalk 0.9 & stearic acid 0.1%
*Ref:* C.H.Winning, USP 2733139(1956) & CA **50**, 6796(1956)

**Casthelaz & Désignolle** proposed in 1867(BritP 3469) several expl compns of which the following might be considered as typical: a)K picrate 55 & K chlorate 45% b)K picrate 35, K chlorate 47 & K ferrocyanide 18% c)K picrate 37, K chlorate 18 & Pb chromate 45 d)Pb picrate 43, K chlorate 16 & Pb chromate 41% e) Pb picrate 37, K chlorate 26, Pb chromate 35 & charcoal 2%
*Refs:* 1)Cundill(1889) in MP **5**, 318(1892) 2) Daniel(1902), 189

**Casting, Centrifugal.** See Centrifugal Casting

**Casting of Explosives.** See under Loading of Ammunition

**Casting Powder.** See under CAST PROPELLANTS

**Casting Powder No 1.** See Corditite Casting Powder under CORDITES

**Casting Solvent.** See under CAST PROPELLANTS

**Casting Techniques for Explosives.** See under Loading of Ammunition

**CAST PROPELLANTS.** These proplnts (not to be confused with Molded Composite Propellants) are obtained by filling a mold contg granules of a proplnt material with a plasticizing liquid, and heating the resulting mixt until a fairly homogeneous mass is obtained

By using casting techniques, it is possible to obtain grains of any desired shape or size. The work on prepn of cast proplnts for use in rockets was initiated in the US in 1944 (Addnl Ref e)

Casting of proplnts techniques may be subdivided into: A)Manuf of cast homogeneous proplnts B)Manuf of proplnts by slurry casting and C)Manuf of cast composite proplnts
*A)Manuf of Cast Homogeneous Propellants.* This includes, solvent, solventless- or ball-proplnts as starting materials. The method consists of the following operations:
a)Prepn of Casting Powder. A colloided proplnt which incorporates NC and other ingredients is made into cylinders ca 0.035" in diam & length (using the standard solvent extrusion method) or made into spheres ca 0.03" in diam (using the process described under BALL POWDER)
b)Prepn of Casting Solvent. A liquid expl plasticizer, such NG, NG + NGc or DEGDN is mixed with non-expl plasticizer, such as DBuPh, DMePh or triacetin and a stabilizer, such as EtCentr. The resulting mixt is evacuated to remove air and volatiles
c)Prepn of Mold(Beaker). A mold for solid rocket proplnt grains having internal burning configuration, is prepd from a cellulose acetate or ethyl cellulose sheet("inhibitor"), 1/8 to 1/2" thick, by wrapping and cementing it about a cylindrical mandrel to form a cylinder of required diam. The bottom end of the cylinder is closed with a plastic disc and the ensemble is placed inside a heavy-walled container, which has provisions for attaching the cores(usually made of Al) which form the perforation of the grain (Ref 2,pp 58-9 & Ref 3,p 249)
c)Filling Operation. With the cores in place, the

beaker is filled to two-thirds of available space with "casting powder". After closing and sealing the top of beaker, the entire unit is evacuated to remove air, residual moisture and other volatiles trapped among the granules. The interstitial spaces remaining betw the granules of casting powder are now filled with casting solvent, also evacuted prior to use. Filling may be done from the top of the mold, from the bottom, or radially from perforated cores. The rate of filling should be fast enough so that the total quantity can be added before the swelling of the granules can appreciably interfere with the flow. After the solvent fills all the interstices betw the individual grains, the feeding is stopped and the beaker is sealed

d)Curing. In this operation the beaker with contents is heated at 60°(140°F) in an oven until the solvent penetrates the granules making them coalesce into a single, nearly homogeneous mass. Since this is purely a physical phenomenon, there is practically no shrinkage on curing. When using ball proplnts as casting powders, the grains do not entirely lose their original shape on curing, because they have a case-hardened outer shell. Such cast proplnts are more fragile than the original grains

After curing, the cast is annealed by a gradual cooling procedure and inspected by x-rays for possible defects(such as voids) and then machined to conform to required dimensions. This type of cast proplnt is not "case-bonded" to the walls of the rocket motor chamber and does not possess the added strength afforded by such bonding (Ref 2,pp 58-60)(See also Ref 1,pp 102-4 and Addnl Refs a,b & c)

Compns of some "casting powders" and "casting solvents" are given in Addnl Refs d, e & f)

*B)Manuf of Propellants by Slurry Casting.* In order to increase the versatility of the casting process a number of methods have been developed which avoid the necessity of making "casting powder". All the ingredients are simply blended in a mixer, generally under vacuum, and the resulting "slurry" poured into the mold and "cured" at 60°. The critical feature is the form of the NC, the fibrous form being inadmissible because of its high rate of swelling and soln. Various types of colloided NC have been used, including granules of a few microns in diam. One variation of slurry cast proplnt developed by Hercules Powder Co, uses a partially colloided form of NC, called "densified" with an av particle size of 250 microns

The slurring methods have the advantage of greater simplicity and versatility, and lower cost than the standard casting process(Ref 3,p 251)

Slurrying methods have been used in prepn of some cast composite proplnts (See also AddnlRefs g,h,j,l & m)

*C)Manuf of Cast Composite Propellants.* Composite proplnts, based on inorg salts as oxidizers and organic plastics as fuel-binders, can be manufd as "free-standing" and "case-bonded" charges. The free-standing chges can be made either by extrusion or by casting into a beaker similar to the procedure described above under Manuf of Cast Homogeneous Propellants (See also Ref 2,p 60)

When the rocket chamber is used as the mold for casting the proplnt, the charge is called "case-bonded". For this the inner surface of the chamber must be cleaned and sprayed with some binder material which acts also as an inhibitor. Along with chamber prepn comes the prepn of cores or "risers" which provides the mold for the perforations of the grain. The material used for casting is obtained by adding a finely ground oxidizer of required particle size to the "premix". The "premix" is prepd by blending the fuel binder with the necessary curing agent, inert additives, and ballistic modifiers as described in Ref 2,pp 62-4. After adding the oxidizer and thoroughly blending it with premix, the resulting "slurry" is poured into the rocket chamber. After the cores are lowered into the chamber and secured in place, the chamber is placed in the "curing" oven where the temp is gradually raised to as high as 300°F(149°C). After "curing" is complete the cores are removed, excess proplnt cut away, and the nozzle assemblies attached(Ref 2,pp 64-5)

Following are examples of cast composite proplnts: a)*Aeroplex* proplnts are prepd by mixing Amm or K perchlorate with resin, as a binding material and pouring the resulting slurry into a mold (See also Vol 1,p A108-R) b) *Plastisol* proplnts are made of approx 75% Amm Perchlorate and 25% of a mixt in equal parts of finely divided polyvinyl chloride and non-soluble plasticizer. The mixt solidifies when heated c)*Polysulfide* proplnts are prepd by suspending granular Amm perchlorate in a polysulfide synthetic rubber mixed with small quantity of ingredients which serve as vulcanizing agents, reinforcing agents, and burning-rate accelerators. The resulting slurry is cast into the rocket

motor chamber and cured from 1 to 3 days at 200°F(ca 93°C)(Ref 4,pp 32-3). The polysulfide rubber has been used in Thiocol proplnts(Ref 2,p 62)(See also Ref 1,pp 101-2 and AddnlRef a)

*Refs:* 1)R.A.Connor, Edit, "Summary Technical Report of Division 8, NDRC," Vol 1, Washington, DC(1946), 89(Casting techniques); 101-2(Cast perchlorate proplnts); 102-4(Cast double-base proplnts) 2)F.A.Warren, "Rocket Propellants", Renhold, NY(1958), 58-68 3)R.Steinberger, pp 249-51 in "The Chemistry of Propellants", A Meeting Organized by the AGARD Combustion and Propulsion Panel, Paris, France in June 1959, Pergamon Press, NY(1960), 249-51 4)B.Kit & D.S.Evered, "Rocket Propellants Handbook," Macmillan, NY(1960), 32-3

*Addnl Refs:* a)OSRD Report **5580**(1945)(Techniques of prepn of cast double-base proplnts) a$_1$)OSRD Rept **5582**(1945)(Cast perchlorate proplnts based on thermosetting high polymers) b)OSRD Rept **5593**(1945)(Experimental study of factors affecting the stability and consolidation of cast proplnts) c)OSRD Rept **5759**(1945)(Studies relating to the development of cast proplnts with special reference to the mechanism of consolidation) d)OSRD Rept **6298**(1945) [Cast double-base jet proplnt prepd by adding to the grains of "casting powder", consisting of NC(12.6% N) 89, DNT 10 & stabilizer 1%, placed in a mold the "casting liquid" consisting of a mixt of NG & triacetin] e)OSRD Rept **5577**(1946) [A general survey of the development of cast double-base proplnts by NDRC as of Nov 1945. The recommended proplnt was prepd from the "casting powder" consisting of NC(13.15% N) 74, NG 20, DEtPh 5 & EtCentr 1% with carbon black, added 0.5% to which was added the "casting solvent" consisting of NG 65, DMePh 34 & EtCentr 1%] f)S.Wachtell, PATR **1731**(1949)(Chromatographic-spectrographic method for detg DEtPh in Type 1 casting proplnt) g)C.Ribaudo, PATR **2014**(1954)(C) h)S.M.Kaye, PATR **2015**(1954)(C) i) A.H.Castelli et al, PATR **2021**(1954)(U)(Simple, rapid IR analysis of "casting solvent", such as one contg NG 70, triacetin 29 & 2-nitro-DPhA 1%) j)C.Ribaudo, PATR **2071**(1954)(C) k) J.Reinhart et al of NOL, "Nitrasol Propellants-Composite Propellant Formulations Based on a Plastisol-Nitrocellulose-Pentaerythritol Trinitrate Binder"(U), Bull of the 14th Meeting of the Joint Army-Navy-Air Force Solid Propellant Group, Johns Hopkins University, Silver Spring, Md(1958)(Conf)(Not used as a source of info) l) J.J.O'Neill, Jr, USP 2916775(1959) & CA **54**, 8088(1960) [Large grains of rocket proplnt are prepd by treatment of NC proplnt spheres ca 0.001" in diam (such as described under BALL POWDER) with at least 25% by vol of dewatered deterrents, such as DBu-phthalate or sebacate, DiMe-sebacate or phthalate, triacetin, etc. For double-base proplnts, NG, DEGDN, NGc or Butanetriol Trinitrate is incorporated. For example, 56.18 parts of spheres(consisting of 12.6% N-NC 87.7, DNT 11, EtCentr 1 & C black 0.3%) were held at 10mm in a "sigma-blade mixer" for 16hrs. Then 37 parts of similarly treated liq mixt(consisting of NG 74, DMePh 25 & EtCentr 1%) was added with agitation. Agitation was continued until even distribution of spheres in liquid was achieved. After pouring the slurry into a mold, it was heated at 75° until the spheres were substantially dissolved. When cool, the uniform grain was removed from the mold] m) D.W.Ryker, USP 2917379(1959) & CA **54**, 8088(1960)(Same as above, but the hot mixt is not poured into molds but into a worm- or screw-feed app, such as "Moyno" pump, heated to 75-80° so that complete soln of spheres is attained. Then the mixt is extruded and cut into grains of desired length) n)A.Andrew, USP 2929107(1960) & CA **54**, 11561(1960)(Prepn of globules 0.002-0.004" in diam of colloided NC suitable as primary materials in plastics or in cast proplnts) o)A.W.Sloan & D.J.Mann, USP 2931800(1960) & CA **54**, 14722(1960)(Prepn of small, dense particles of NC suitable as primary materials in lacquers or cast proplnts) p)V.Grassie, USP 2946673(1960) & CA **54**, 21764(1960)(Prepn of a cast double-base proplnt by combining in a mold granular NC having a bulk d of at least 25 lb/cu ft with a casting liquid consisting of NG and desensitizing plasticizers. The granular NC is produced by agitating fibrous NC in an aq bath contg an org liq which destroys the fibrous structure of the NC without dissoln) r)Anon, "Cast Double-Base Propellants", pp 186-95 in Vol 2 of "Complete Draft Manuscript ORDP **20-176**, Explosives Series, Solid Propellants", Hercules Powder Co, Wilmington, Del(1960)(Conf)(Not used as a source of info) s)Allegany Ballistics Laboratory, "Status of Research and Engineering Projects", ABL/QPR-35, Contract NOrd 16640(Dec 1, 1961-Feb 28, 1962)(Conf)(Not used as a source of info) t)Imperial Chemical Industries Ltd, "Research and Development Work on Cast Double-Base Propellant Rockets", (Feb 1962)(Conf)(Not used as a source of info)

**Castor Oil**(Ricinus Oil). A pale yel to colorless, very viscous oil, consisting mostly(ca 80%) of ricinolein (triglyceride of ricinoleic acid), $C_3H_5(C_{18}H_{33}O_3)_3$; fr p ca -10°,d 0.957 to 0.967 at 15.5/15.5°, $n_D$ 1.476-1.478 at 25°, viscosity 6-8 poises at 25°, saponification value 178 and iodine value 85; sol in alc, eth, benz, chlf & $CS_2$. Three commercial grades are available in the US: USP XIII, No 1 & No 3. Castor oil is derived from the seeds of the plant Ricinus communis by cold -pressing for the first grade of medicinal oil and by hot-pressing for technical grades. The USP grade oil is used in medicines(as purgative) and in cosmetics, while tech grades are used as high -grade lubricants (especially for internal combustion engines,)(such as in airplanes), as hydraulic fluid in brakes, as recoil fluid for guns, as softener in NC lacquers & in artificial leather finishes, in manuf of transparent soaps, and in resins & plastics(Refs 2,5 & 9)(See also Ref 10 and AddnlRefs f,g,h & i)

Castor oil has also been used in some expl and pyrotechnic compns mostly as a coating agent to reduce the hygroscopicity and sensitivity(to shock and friction) of some ingredients

Below are examples of French Cheddites (Street Explosives) using castor oil:

Accdg to Weingarten(Ref 12), castor oil has been used in some US pyrotechnic compns, but there is a tendency to replace it, as well as other natural oils, with synthetic materials. Following are examples of US compns using castor oil: a) Sr nitrate 50, Mg 30, Ti oxide 10, polyvinyl chloride 6, castor oil 2 & linseed oil 2% b)Ba nitrate 76, Al flakes 6, Al atomized 12, sulfur 4 & castor oil 2%

Izzo(Ref 6) lists the following pyro compns using castor oil: a)White star for French military signal cartridge used in Véry pistol: Ba nitrate 57, Al powd 30, Sb sulfide 6, cryolite 6 & castor oil 1%(p 226) b)White star with parachute: Ba nitrate 70.5, Al powder 19, Al grains 9.5 & castor oil 1.0% (p 227) c)Green star with parachute: Ba chlorate 90, shellac 8 & castor oil 2% (p 227) and d)White pyrotechnic light:Ba nitrate 74, K nitrate 6, Al powder 22, gum arabic 4 and castor oil 6%(p 239)

Kirk & Othmer(Ref 7,p 323) lists the following illuminating flare compns employing castor oil: a)Ba nitrate 36, Mg(coated with 6% of linseed oil) 42, Al 8, Na oxalate 12, linseed oil 1 & castor oil 1% and b)Ba nitrate 68, Al 21, Na oxalate 5, sulfur 4 & castor oil 2%

*Castor Oil, Dehydrated.* Heating of castor oil to 200-240° in the presence of catalysts, such as Sn or Ti oxides yields a partially dehydrated oil which is miscible with mineral oils. It was used during WWI under the name of "Castorlubrin" for lubrication of aircraft engines, but was replaced later by high grade mineral lubricating oils. It is still widely used in brake fluids, shock absorbers, and shimmy damper systems. It is also frequently used in combination with light mineral oils, glycols, etc.

Heating of castor oil to 250-300° in the presence of catalysts(direct method) or by employing one of the indirect methods, such as described in Ref 5,p 243, produces completely dehydrated oil. This oil possesses good drying props and is widely used as a substitute for tung oil. The term "dehydrated castor oil" is used to denote this type of oil (Ref 5,pp 241-3)(See also Ref 11)

*Castor Oil, Hydrogenated.* Since ricinoleic acid is an unsaturated acid, hydrogen can be added to its double-bond, yielding a satd acid of higher mp with max ca 87°. Hydrogenation may be conducted by introducing hydrogen under pressure into the thoroughly agitated oil at temps of the order of 150° and in the presence of a Ni catalyst. It can

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| K chlorate | 70.0 | – | 75.0 | 74.6 | 80.0 | 80.0 | 79.0 | – | – | – |
| Na chlorate | – | – | – | – | – | – | – | 79.0 | – | – |
| Amm perchlorate | – | – | – | – | – | – | – | – | 82.0 | 50.0 |
| Na nitrate | – | 80.0 | – | – | – | – | – | – | – | 30.0 |
| Picrino-napthalene | – | 10.0 | 20.0 | – | – | – | – | – | – | – |
| DNB | 11.6 | – | – | – | – | – | – | – | – | – |
| MNN | – | – | – | 5.5 | 12.0 | 13.0 | 1.0 | – | – | – |
| DNT | – | – | – | – | – | 2.0 | 15.0 | 16.0 | 13.0 | 15.0 |
| Starch | 9.2 | – | – | 14.9 | – | – | – | – | – | – |
| Castor oil | 9.2 | 10.0 | 5.0 | 5.0 | 8.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| Refs | 1 | 1 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |

be used as a substitute for waxes(Ref 5,pp 243-4)

*Castor Oil, Nitrated.* Brighton(AddnlRef a) prepd, by treating castor oil with dil nitric acid, a reddish-brn viscid oil with Ncontent betw 2.3 & 3.8% and d ca 1.05. The substance was sol in acet, eth & AcOH, but insol in $CS_2$. It did not decomp at 100° but slowly darkened. Radcliffe & Polychronis(Addnl Ref b)nitrated castor oil and ricinoleic acid (as well as some other fatty acids) with concd or 99% fuming nitric acid and obtained products of low N content. Keck(Addnl Ref c) patented a proplnt consisting of NC and nitrated castor oil

*Castor Oil, Oxidized.* Heating of castor oils in intimate contact with air or oxygen at temps of 80 to 130°, with or wo a catalyst, produce oils of high viscosity and higher d, than untreated castor oils. The oxidized oils, known also as "blown oils" are used as plasticizers in lacquers, artificial leathers, oil cloths and similar products (Ref 5,p 241). It was claimed by Nakamura (AddnlRef d) that a small quantity of peroxide was formed when castor oil was treated with air at ca 155°. Mondain-Monval & Marteau(Addnl Ref e) claimed that direct oxidation of castor oil (as well as of some other vegetable oils) by air in a heated glass tube also produced peroxides

*Refs:* 1)Daniel(1902), 472 2)Thorpe **2**(1938), 420-22 3)CondChemDict(1942), 288(Cheddites) 4)Davis(1943), 258, 269, 358-60 & 365 5)Kirk & Othmer **3**(1949), 237-44 6)Izzo, Pirotecnia(1950), 226-7 & 239 7)Kirk & Othmer **11**(1953), 323 8) Sax(1957), 444(Toxicity & fire hazard of castor oil) 9)CondChemDict(1961), 229 10)US Specification JJJ-C-86(Castor oil, technical) 11) US Military Specifications MIL-C-15179A(Castor oil, dehydrated) 12)G.Weingarten, PicArsn, Dover, NJ;private communication(1962)

*Addnl Refs:* a)R.Brighton, JSCI **36**, 984-6(1917) & CA **12**, 98(1918)(Nitration of castor oil with dil nitric acid) b)L.G.Radcliffe & C.Polychronis, JSocDyers Colorants **36**, 65-76(1920) & CA **14**, 3330(1920)(Nitration of castor oil and of ricinoleic acid with concd and 99% fuming nitric acid) c)C.H.Keck, USP 1651459(1927) & CA **22**, 870(1928)(A proplnt consisting of NC and nitrated castor oil) d)M.Nakamura, JSocChemInd Japan **40**, 229(1937) & CA **31**, 7681(1937) (Formation of small quantity of peroxide on treating castor oil with air at ca 155°) e) P.Mondain-Monval & S.Marteau, AnnCombustibles Liquides **12**, 923-8(1937) & CA **32**, 3154(1938) (Formation of peroxide by heating castor oil with air in a glass tube) f)J.E.Good, Paint Varnish Production Mgr **23**, 3-4, 6 & 8-10(1943) & CA **37**, 3961(1943)(Castor oil in war and industry) g) A.Kraus, Farbe u Lack **57**, 433-7(1951) & CA **46**, 1777-8(1952)[Uses of raw castor oil and of oxidized castor oil(known as "blown castor oil" or Limorol) in NC lacquer films] h)A.Kraus, Ibid **60**, 185-6(1954) & CA **48**, 12422(1954) (Lacquers made of NC & castor oil were only slightly yellowed when exposed to sunlight, but they did not pass the "fold" test) i)K.Murai et al, JOilChemists'Soc, Japan **3**, 2-6(1954) & CA **50**, 250(1956)(Study of plasticizers for polyvinyl chloride obtained from castor-oil fatty acid, and lower fatty acids of coconut oil)

**Castor Oil, Analytical.** See "ASTM Standards" (1955), Part 4, **D555-54**, pp 234-56(Tests of drying oils, such as castor oil); **D960-52**, 367-8 (Std specs and tests for raw castor oil); **D961-55T**, 224-5(Tentative specs and tests for dehydrated castor oil)

**Castro Powder.** An Amer expl proposed in 1884; K chlorate 50.00, bran 43.75 & Sb sulfide 6.75%

*Refs:* 1)Daniel(1902), 118 2)Pérez Ara(1945), 213

**Catactines.** Expls patented in 1888 by Chandelon for use in grains or compressed. They consisted of mixts of one of the organic picrates or chloropicrates with sulfur, carbon and an oxygen carrier, such as a nitrate or chlorate of alkaline or alkaline-earth metals

*Refs:* 1)Cundill(1889) in MP **5**, 306(1892) 2) Daniel(1902), 118

**Catalysis.** It may be defined as the effect produced on the rate of reaction either by a small quantity of a substance(called "catalyst"), which appeares to be unchanged in the reaction products, or by some physical energy, such as radiation, electricity or magnetism. Reactions accelerated by catalysts are called "positive catalytic reactions", while those retarded are known as "negative catalytic reactions". The Phenomenon of catalysis is essentially a branch of "surface chemistry"

*Historical.* Accdg to Kirk & Othmer(Ref 12,p 245), the fact that a chem reaction can be aided by the addn of certain substances was known to the alchemists in the Middle Ages and by the end of 18th and beginning of 19th century several industrial processes were known such as hydrolysis of starch by acids(Parmentier, 1781) and the lead-chamber sulfuric acid manuf

(Clement & Desormes, 1806). Berzelius described and classified in 1836 the known reactions in which the rate was altered by the presence of certain substances, under the name of "catalysis"

The most important work on catalysis was done, however, in the present century, first in France by Sabatier(in collaboration with Sanderens) and in Russia by Ipatieff(in collabn with Zelinsky & others). In Germany the work was done by Haber & the IG Farbenindustrie group; in England by Hinshelwood & Rideal; and in US by Langmuir & Taylor

At present catalytic processes are used on a very large scale for the prepn of both inorg and organic compds

Following are examples of catalytic processes which are of interest for those working in explosives or ammunition plants: a)Combination of hydrogen and nitrogen to form ammonia in presence of ferric oxide catalyst at 400 to 600° and 200 to 1000 atm pressure b)Oxidation of ammonia to nitrogen oxides in presence of Pt gauze as catalyst c)Oxidation of sulfur dioxide to trioxide in presence of vanadium pentoxide at 500° d)Catalytic prepn of benzene and toluene from petroleum. Nitration of benzene and toluene yields high expls, such as TNB and TNT

*Refs:* See under Catalyst

**Catalyst or Catalyzer.** It is a substance which affects the speed of a reaction, (or even starts it), but remains chemically unchanged at the end. It is known, however, that catalysts may take part in some reactions and may be physically changed. For more info on catalysts, see Refs

*Refs:* 1)P.Sabatier, "La Catalyse en Chimie Organique", English Translation, Wiley, NY (1923) 2)W.Langenbeck, "Die Organischen Katalysatoren", Springer, Berlin(1935) (Lithoprinted by Edwards Bros, AnnArbor, Mich) 3)V.N.Ipatieff, "Catalytic Reactions at High Pressures and Temperatures", Macmillan, NY (1937) 4)Thorpe **2**(1938), 422-9(Catalysis in industrial chemistry) 5)S.Berkman, J.C. Morrell & G.Egloff, "Catalysis, Inorganic and Organic", Reinhold, NY(1940) 6)G.M.Schwab, "Handbuch der Katalyse", Vols 1-7, Springer, Wien(1940-1943)(Lithoprinted by Edwards Bros, AnnArbor, Mich) 7)Davis(1943), 276-7 & 377 8) H.W.Lohse, "Catalytic Chemistry", ChemPubgCo, NY(1945) 9)H.E.Emmett, "Catalysis and Its Industrial Applications", pp 214-42 in vol 6 of J.Alexander's, "Colloid Chemistry", Reinhold, NY(1946) 10)R.H.Griffith, "The Mechanism of Contact Catalysis", OxfordUnivPress, London (1946) 11)W.G.Frankenburg, VI.Komarewsky & E.K.Rideal, Edits, "Advances in Catalysis and Related Subjects", Academic Press", NY, Vols 1-10(1948-1958) 12)Kirk & Othmer **3**(1949), 245-72(Catalysis) 13)S.G.Gregg, "The Surface Chemistry of Solids", Reinhold, NY(1951), 245-70(Catalysis and chemisorption) 14)P.H. Emmett, Edit, "Catalysis", Reinhold, NY Vols 1-7(1954-1960) 15)E.Molloy & E.Carr, "Catalysts", Newness, London(1955) 16)V.I. Komarewsky et al, Edits in Vol 2 of Weissberger's "Technique of Organic Chemistry", Interscience, NY(1956) 17)Kirk & Othmer, FirstSuppl(1957), 144-50(Catalysis) 18)C.H.Collier, Edit, "Catalysis in Practice", Reinhold, NY(1957) 19)A.V.Topchiev, "Boron Fluoride and Its Compounds as Catalysts in Organic Chemistry", Translated from the Russian by J.J.Greaves, Pergamon Press, NY(1959) 20)J.E.Germain, "Catalyse Hétérogène", Dunod, Paris(1959)

*Addnl Refs:* a)W.Brün, USP 2111203(1938) & CA **32**, 3617(1938)[Incorporation in a priming mixt (such as contg Pb thiocyanate, Ba nitrate and LST) about 2%, or less of a catalyst, is claimed to accelerate the reaction and to lower the temp. These catalysts included metals or alloys(such as Ag, Bi, Cu, Fe or Pt), oxides(such as $MnO_2$, CoO) or a salt of metallo-acid(such as Na tungstate)] b)Katalyst-Chemie AG, FrP 821767 (1937) & SwissP 192363(1937); CA **32**, 3964 & 4173(1938)(Use of catalysts, such as Cr, W, Mo-Ta-Ni, V, Ga or In in nitration of naphthalene, glycerin & other org compds) c)G.F. Hennion, USP 2314212(1943) & CA **37**, 5077 (1943)(Use of $BF_3$ as catalyst in nitration of cyclic org compds) d)M.Senkus, USP 23332491 (1944) & CA **38**, 1749(1944)(Use of reducing agents such as S,C,acetone or 2-nitroheptane as catalysts in liq-phase nitrations of satd aliphatic hydrocarbons) e)N.A.Valyashko et al, TrudyKhar'kovKhim-TekhnolInst No **4**, 48-59 (1944) & CA **42**, 1218(1948)(Nitration of toluene with $NO_2$ without $H_2SO_4$, but in presence of catalysts) f)N.Levy, USP 2394315(1946) & CA **40**, 2454(1946)(Use of silicate catalysts contg Ag or Sb or both in prepn of nitroparaffins) g)C.V. Caesar & M.Goldfrank, JACS **68**, 372-5(1946) & CA **40**, 3633(1946)(Use of NaF as catalyst in nitration of starches with $N_2O_5$) h)B.Hass & H.Stecher, IEC **39**, 817-21(1947) & CA **41**, 5436 (1947)(Use of catalysts in vapor-phase nitrations of satd hydrocarbons) i)A.E.Rout, BritP 586732

(1937) & USP 2431585(1947); CA **41**, 6897(1947) & **42**, 1605(1948)(Use of catalysts in vapor-phase nitrations of aromatic hydrocarbons) j)R.M. Schramm & F.H.Westheimer, JACS **70**, 1782-4 (1948)(Use of catalysts in nitration of anisole) k)W.J.Chute et al, CanJRes **26B**, 89-103 & 114-37(1948); CA **42**, 4918 & 4919(1948)(Catalyzed nitration of amines) l)A.I.Titov & A.N. Baryshnikova, ZhObshchKhim **17**, 829-35(1947) & CA **42**, 3340(1948)(Mechanism of nitration of aromatic compds in the presence of mercury salts) m)T.Connor, CanJRes **26B**, 294-308(1948) & CA **42**, 5844(1948)(Use of catalysts in nitration of secondary aliphatic amines) n)N.Levy et al, USP 2455425(1948) & CA **43**, 2220(1949)(Nitration of paraffins with $NO_2$ in presence of catalysts) o)K.W.Gee, USP 2464572(1949) & CA **43**, 4285 (1949)(Use of catalysts in prepn of nitroparaffins) p)A.I.Titov & N.G.Laptev, ZhObshchKhim **19**, 229-39 & 267-78(1949); CA **44**, 5828(1950) & **43**, 6585(1949)(Mechanism of catalytic nitration of aromatic compds in the presence of Hg salts) g)G.S.Samuelson et al, JACS **72**, 3872-4(1950) & CA **45**, 2885(1951)(Hydrogenation of nitrocompds with Raney Ni treated with chloroplatinic acid and with alkali) p)J.A.Grand & R.Miller, USP 2555333(1951) & CA **45**, 7337(1951)(Use of Cu chromite as combustion catalyst in solid compressed fuel, such as mixt of NGu 75 & GuN 25%) r)Anon, ChemEngrg **1951**, June, p 183 (Catalytic process for waste disposal developed by D.V.Moses and put into operation at DuPont's Belle Plant, West Virginia, consists of vapor -phase catalytic destruction of organic wastes by oxidation to $CO_2$ & $H_2O$. It was claimed that the method is more convenient than bio-oxidation and less expensive than non-catalytic oxidation at high temp) s)E.L.Blackall et al, JCS **1952**, 28-32 & CA **46**, 9392(1952)(Use of $HNO_2$ as catalyst in nitration of aromatic compds) t) Krupp Treibstoffwerk GmbH, GerP 831393(1952) & CA **52**, 10144(1958)(Nitration of satd nonaromatic hydrocarbons with $NO_2$ in presence of catalytic amts of free radicals, such as $PbEt_4$, azomethane, azobenzene or triethylmethyl) u)G.B.Bachman & J.V.Hewett, USP 2597698(1952) & CA **47**, 2766 (1953)(Use of small amts of free halogens as catalysts in vapor-phase nitration of aliphatic hydrocarbons) v)C.C.Price & C.A.Sears, JACS **75**, 3276-7(1953) & CA **49**, 6153(1955)(Nitration of aromatic compds with nitryl chloride, $ClNO_2$, in presence of catalysts, such as HF, $AlCl_3$ or $BF_3$) w)P.Pascal et al, MP **35**, 335-47(1953) [In order to det the influence of presence of various salts on combustion of proplnts, Pascal et al conducted a series of experiments commencing with combstn of carbon in atm of nitric oxide. As catalysts, the salts of K, Na, Cs, Rb, Sr & Cu were tried. The best results were obtained with K bitartrate and then followed Na dinitronaphtholsulfonate(Yellow OS), K chloride, Na carbonate & Sr chloride] x)J. Cason et al, USP 2686804(1954) & CA **49**, 2075 (1955)(Use of Br or Br compds as catalysts in nitrating secondary amines or their nitrates with mixts of 98% nitric acid and acetic anhydride) y) J.A.Hannum, USP 2692194 & 2692195(1954); CA **49**, 2736-8(1955){Addn of small amts of substances, such as the pyridine salt of uranylacetylacetonate, $[UO_2(C_5H_7O_2)_3H.C_5H_5N]$, or of the alkylamine chromates or dichromates to liq nitroaliphatic fuels catalyzes the combustion reaction by promoting smooth burning without lowering expln temp of the fuel} z)A.I.Titov & A.N.Baryshnikova, ZhObshchKhim **24**, 2005-8 & 2040-4(1954); CA **50**, 10667(1956) & **49**, 14659 (1955)(Mechanism of catalytic nitrations of aromatic compds) aa)S.Z.Roginskii, ReferatZh-Khim **1956**, Abstr No 53971 & CA **53**, 3857(1959) (Mechanism of catalysis on the basis of isotope data) bb)M.A.Cook & F.A.Olson, C & EN **34**, 4434-6(1956) & CA **50**, 17453(1956)(Catalyzed explns occurred with hydrogen-oxygen stoichiometric mixts and also with hydrogen -oxygen-argon mixts when 14-15 mole % of argon had been incorporated in a steel mixing tank) cc) G.R.Thomas, USP 2877263(1959) & CA **53**, 14010(1959)(Use of catalysts in nitration of an ester of N-monoalkyl-substituted carbamic acid) dd)K.Okoń, BiulWojskowejAkadTech in JaroslawaDobrowskiego **8**, No 1 PraceChem 116-20(1959) & CA **54**, 19547(1960)(Use of picric acid as catalyst in nitration of benzene, toluene, naphthalene and chlorobenzene)

**Catalyst**(Rocketry). A liq or solid substance which, by its contact with a "monoreactant" fluid, increases the breakdown or reaction rate, without itself becoming altered in nature or amount. One of the earliest known rocket applications of a catalyst was in a Ger ATO engine, The "Walter 109-500". Liquid Ca permanganate was sprayed in the thrust chamber of the motor to make contact with the primary spray of concd $H_2O_2$. The catalyst caused the nearly instantaneous breakdown of this mono -proplnt into hot steam and oxygen. Other catalysts considered or tried include: Na

permanganate, K permanganate, Mn dioxide & Fe oxide
*Refs:* 1)A.J.Zaehringer, "Solid Propellant Rockets", AmRocketCo, Wyandotte, Mich(1955), 50-1 2)Rocket Encycl(1959), 71

**Catalytic Ignition**(Rocketry). A method of igniting the main proplnts in a rocket combustion chamber by utilizing a solid or a liq catalyst to initiate chem decompn or breakdown of one of the proplnts and thereby to generate ignition temp and pressure
*Ref:* Rocket Encycl(1959), 73

**Catapult**(Ancient). One of the "engines of war" used in ancient times for projecting long darts, stones and javelins. There were different kinds and sizes of catapults to which various names were given. The smaller kinds were in the form of Arbalest(Crossbow), which is briefly described in Vol 1,p A477 of this Encyclopedia. The larger catapult consisted of a powerful wood, horn or steel bow fastened transversely to a stand and wound up by means of a windlass fastened upon another stand. One of the varieties could discharge a whole flight of darts simultaneously and might be considered as the earliest machine gun. The catapult was smaller and less powerful than the Ballista(qv) and discharged projectiles at low angle of elevation. Some authorites consider the catapult as one of the Mangonels(qv)(See also Trebuchet)
*Refs:* 1)Greener(1881),p 7 & Fig 4,p 8 2) Farrow's MilitEncycl **1** (1895), 309-10 3)W.L. Rogers, ArOrdn **15**, 339, Fig 5(1935) 4) EncyclBritannica **5**(1952), 23 & **8**(1952), 453 5) Merriam-Webster's(1961), 351

**Catapult**(Modern). Any mechanical device utilizing the recoil of a spring for hurling grenades or bombs. Also a device for launching an airplane at flying speed, as from an aircraft carrier. It is usually a carriage accelerated on a track by deflagration of a proplnt chge or by hydraulic or steam pressure. This term is also applied to a device moving a rocket or guided missile into the air from a ramp or track and for ejecting a person from an aircraft(See also under Cartridge Activated Devices)
*Refs:* 1)Glossary of Ord(1959), 62 2)Merriam -Webster's(1961), 351

**Catapult Take-off.** See Assisted Take-off(ATO) in Vol 1,p A497-R of this Encyclopedia

**Catechol.** See Pyrocatechol

**Catergol.** A Ger code name for a rocket propellant system using catalyst for decomposition
*Ref:* A.J.Zaehringer, "Solid Propellant Rockets", AmerRocketCo, Wyandotte, Mich(1955), 149

**Cathode Ray, Cathode Ray Tube and Cathode Ray Oscillograph.** Cathode ray is an emission from the cathode(negative electrode) of a discharge tube, consisting of negatively charged particles(electrons). The ray is projected at right angle to the surface of the cathode. The discharge of the tube may be caused either by alternating high-potential current or by a series of spark discharges. The electrons emitted by the cathode travel in straight lines unless deflected by the action of a magnetic or electric field. They differ from beta-rays only in having lower velocities

Cathode rays have many applications, such as in the *cathode-ray tube* and the *cathode-ray oscillograph.* The former is a vacuum tube in which the deflection of an electron beam indicates on a fluorescent screen instantaneous values of the actuating voltages or currents. The oscillograph incorporates a cathode ray tube and is used extensively in ballistics, such as for photographying rapid events(See under Cameras, High-Speed, Photographic)
*Refs:* 1)C.Cranz, "Lehrbuch der Ballistik", Ergänzungsband(1936), 163 2)J.T.MacGregor -Morris, "Cathode Ray Oscillography", Chapman & Hall, London(1936) 3)G.Parr, "The Low Voltage Cathode Ray Tube and Its Applications", Chapman & Hall, London(1937) 4)M.Bly, "A Guide to Cathode Ray Patterns", Wiley, NY (1943) 5)J.F.Rider & S.D.Uslan, "Encyclopedia on Cathode-Ray Oscilloscopes and Their Uses", Rider Publisher, Inc, NY(1950) 6)EncyclBritannia **5**(1952), 41 6)J.F.Rider, "Obtaining and Interpreting Test Scope Traces", Rider Publisher, Inc, NY(1954) 7)J.H.Ruiter, "Modern Oscilloscopes and Their Uses", Reinhart, NY (1955) 8)A.Haas, "Oscilloscope Techniques", Gernsback Library, NY(1958) 9)V.N.Laut & A.L. Lyubovich, "The Cathode Ray Tube Memory of the High Speed Electronic Computer of the USSR Academy of Sciences", Translated from the Rus by R.Feinstein, Pergamon Press, NY(1960)

**Cauvet & Baron Explosives.** Two formulations were submitted in 1882 to the Commission Française des Substances Explosives: a)K

chlorate 50 & K ferrocyanide 50% and b)K chlorate 50, K ferrocyanide 25 & sugar 25% (Compare with Augendre Powder, Vol 1,p A507 of this Encyclopedia)
*Ref:* Cundill(1888) in MP **5**, 291 & 306(1892)

**Cavalli, Giovanni**(1808-1879). Ital artillery officer, who introduced many improvements in weapons and ammunition and made Ital artillery one of the best of the world
*Ref:* E.Bravetta, SS **3**, 241-3(1908)

**Cavasenza Figli**, Plant at Casale(Isola). One of the Ital expl plants

**Cavitated Charge or Hollow Charge.** See Shaped Charge

**Cavitation in Explosive or Propellant Charges.** The formation of one or more cavities(air spaces or voids) in cast-loaded solid, expl or proplnt chges is called cavitation (See under Loading of Ammunition). A cavity in a HE chge of a shell may cause premature expln in the gun because of collapse of the chge under the force of acceleration. A cavity in a proplnt chge may affect its ballistic characteristics(Ref 1). Cavities in loaded ammo may be discovered by x-ray devices such as Betatron(qv)

The phenomenon of cavitation occurs also in liq rocket proplnts where the suction pressure is greater than the vapor pressure of the proplnt, and bubbles of gas form(Ref 2)
(See also under Loading of Ammunitition)
*Refs:* 1)Glossary of Ord(1959), 62 2)Rocket Encycl(1959), 73

**Cavité au Bloc de Trauzl ou Épreuve au Bloc de Plomb.** French for Trauzl Block Test, also called Lead Block Expansion Test, but conducted somewhat differently from the procedure used in US or Germany. A brief description of Fr method, also called "Coéfficient d'Utilisation Pratique", is given in Vol 1, p IX of this Encyclopedia

**Cavity.** See under Cavitation

**Cavity Charge.** See Shaped Charge

**Cavity Effect.** Same as Munroe-Neumann Effect, Shaped Charge Effect or Hollow Charge Effect

**Cavity Type Transducer** suitable for making dynamic pressure measurements of ordnance items was discussed by C.L.Pataky, PATR **2321**(1956)(U)

**CBRW.** Abbr for Chemical, Biological, and Radiological Warfare

**CBS.** A plastic HE consisting of RDX 84 & butyl stearate 16% with ca 1.5% stabilizer added
*Refs:* 1)Anon, "Care, Handling, Preservation and Destruction of Ammunition", TM **9-1903**(1956), 77(listed wo giving its compn) 2)Anon, "Ordnance Safety Manual", ORDM **7-224**, C7 to 11W1-2, Table 1905, Group 1, item 3 3)E.P.Vail, PicArsn; private communication (1962)

**CBS-128K and CBS-162A,** Composit rocket proplnts developed by Grand Central Rocket Co. Their compns and props are given in conf "Propellant Manual", SPIA M2(1959), Unit No's 567 & 561

**CC.** Abbr for Chemical Corps

**CC**(Cyclonite-Cannon)**Propellants.** Exptl double-base proplnts, contg RDX in lieu of NG, were developed during WWII by the DuPont Co. Two compns are as follows: a)**CC1**: NC(12.6% N) 37.5, RDX 50.0, butylstearate 12.0 & DPhA 0.5 and b)**CC2**: NC(12.6% N) 36.5, RDX 53.0, butylstearate 10.0 & DPhA 0.5%. About 0.4% of K nitrate could be added as flash-reducer. The proplnt CC2 was intended for use in high-velocity weapons, such as 90mm AT and T guns. The CC proplnts exhibited superior thermochemical props, showed good velocity relationship and better thermal stability than proplnts contg NG. Their disadvantage was poor uniformity from round to round. The manuf and analytical procedures are described in Ref 2(See also CR Propellants)
*Refs:* 1)L.Pauling et al, OSRD Rept **5495**(1945) 2)E.I.DuPont de Nemours & Co, OSRD **6216** (1945) 3)Anon, "Summary Technical Report of Division 8, NDRC", Vol 1, Washington, DC(1946)

**CD.** A Brit "solvent" colloidal proplnt for small arms ammo. Its compn & props are given in conf "Propellant Manual", SPIA M2(1959), Unit No 366

**CDT(80).** A cast, rocket, double-base proplnt developed at ABL. Its compn & props are given in conf "Propellant Manual", SPIA M2 (1959), Unit No 578

**CE**(Composition Exploding). Brit designation of Tetryl(2,4,6-Trinitrophenylmethylnitramine)

**Ceipek's Explosives.** Blasting expls developed before WWI in Austria: a)AN 88, carbonized tumeric pdr 6.25 & wood charcoal 5.75% b)AN 88, carbonized pdr of curcuma root 1.05, carbonized pdr of sandal wood 0.95 & nitrated pdr of curcuma root 10% c)AN 78-87, TNT 4-13.5, carbonized turmeric pdr 5.5-10, carbonized cereal flour 0-3 & NaCl 0-3% d)AN 80-90 & nitrated turmeric pdr 20-10%
*Refs:* 1)N.Ceipek, USP 988244(1911) & CA **5**, 1995(1911) 2)N.Ceipek, BritP's 9742 & 9743 (1911) & CA **5**, 3342(1911) 3)N.Ceipek, USP 1033537(1912) & CA **6**, 2687(1912

**"Celite".** Trademark for diatomaceous earth and a line of products processed from it by Johns-Manville. Celites occur at Lompoc, Calif as white to pale-brownish, porous materials varying in d from 0.24 to 0.34g/cc. They are capable of absorbing 300 to 400% of water by wt. A typical analysis of celite, on ignited basis,is: $SiO_2$ 92.7, $Al_2O_3$ 3.8, $Fe_2O_3$ 1.4, CaO+MgO 1.0 and potash & soda 0.9%; unaccounted materials 0.2%. Celites are used as filter aids, as fillers in plastics, as chromatographic adsorption columns and as catalyst carriers (Refs 1,3 & 4) (See also numerous entries in CA's)

The use of Cellite as component of inert simulants for HE's, was investigated at PicArsn. A mixt contg Celite 10 & crude or semi-refined polychloronaphthalene was found to be suitable for that purpose(Ref 2)

The term Celite is also applied to a soln of dicalcium silicate & dicalcium aluminate used in Portland cement industry(Ref 1)
*Refs:* 1)Gardner'sChemSynonyms(1948), 121 2) A.J.Clear & O.E.Sheffield, PATR, **1618**(1948) (Inerts simulants for high expls) 3)H.Strain, AnalChem **21**, 77(1949)(Use of diatomaceous earth in chromatographic columns) 4)CondChemDict (1961), 233

**Celladyne, Antifrost.** See Antifrost Celladyne in Vol 1,p A466-L of this Encyclopedia

**Cellamite.** An expl contg AN 86.0, NG 12.0, NC (12% N) 0.5 & cellulose 1.5%. It was investigated in 1925 by the Commission des Substances Explosives(CSE) and found to have a CUP value(power by French Lead Block Expansion Test) 83% of PA and detonation velocity 2980m/sec. Its OB to $CO_2$ was positive
*Ref:* L.Médard, MAF **22**, 596-7(1948)

**Cellite.** A plastic compd used in films, etc prepd by mixing an alcoholic soln of the lower acetylated products of cellulose(cellulose acetate) with camphor, followed by drying. Cellite films are less flammable than celluloid films(Ref 2)

The term Cellite has also been applied to the aq soln of Na sulfite used for the purification of crude TNT(Ref 1)
*Refs:* 1)Clift & Fedoroff, **1**(1942), Chap VI,p 3 2)Gardner's Chem Synonyms(1948), 121 3) CondChemDict(1961)-not found

**Cellobiose and Derivatives**

*Cellobiose*(formerly called Cellose), $C_{12}H_{22}O_{11}$; mw 342.30. It seems that *α*-isomer was never isolated. The *β-cellobiose,* col microscopic crysts(from dil alc), contains from 0.25 to 0.5 mole $H_2O$; mp ca 225° with decompn, $[\alpha]_D^{20}$ +34.8°(in 6% aq soln). Can be prepd by treating dry *α*-cellulose octaäcetate with absol methanol in which some Na is dissolved(Ref 2). It can also be prepd by saponification of *β*-cellobiose octaäcetate with alcoholic KOH or by the action of some bacteria on cellulose(Ref 1)
*Refs:* 1)Beil **31**, 380-1 2)OrgSynth **17**(1937), 34 & CollVol **2**(1943), 122

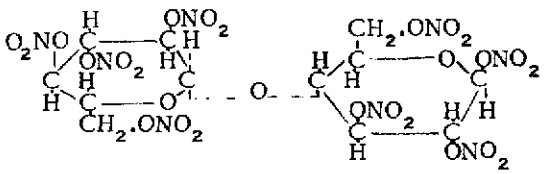
*Cellobiose Octaäcetates,* $C_{28}H_{38}O_{19}$. Its *α-isomer,* ndls or lflts(from alc), mp 220-2°, can be prepd by treating dry absorbent cotton with $AC_2O$ contg some concd $H_2SO_4$(Ref 2), or by other methods(Ref 1). The *β-isomer,* ndls(from alc), mp ca 200°, can be prepd by heating cellobiose with $AC_2O$ & $CH_3COONa$ or by other methods(Ref 1)
*Refs:* 1)Beil **31**, 382-3 2)OrgSynth **17**(1937), 36 & CollVol **2**(1943), 124

**Cellobiose Nitrates.** Two nitrates: *Cellobiose Nitrate A,* N content 8.45%;and *Cellobiose Nitrate B,* N content 13.7% are listed by Berl & Hefter without giving any props except mol wt (Ref)
*Ref:* E.Berl & O.Hefter, Ann **478**, 244(1930) & CA **24**, 4333(1930)

**Cellobiose Octanitrates,** $C_{12}H_{14}N_8O_{27}$; mw 702.30, N 15.93%. Two compds are described in the literature:
*Cellobiose Octanitrate of Ashford et al,* wh

crysts(from 2:1-ether-methanol), mp 154-5°; was prepd by nitrating celloboise with nitric acid(d 1.5) in the same manner as was described in Ref 2 for nitration of starch. The compd was more stable than maltose octanitrate(judging by Abel Test), but it did not pass Bergmann-Junk Test(Ref 3)

*Cellobiose Octanitrate of Fleury et al.* It is claimed that it is β-cellobiose octanitrate and its structural formula is:



wh crysts(from hot methanol by pptn with 3:1-methanol-water); mp 140°, expl at 287° (Maquenne block), d 1.67 at 20°, $[\alpha]_D^{20}$ +22°11' (in 6ps of acetone); very sol in acet & fairly sol in abs alc; dec very slowly at RT and loses ca 35% of its wt when heated at 100° for 20hrs. It was prepd by adding cellobiose in small portions (with agitation) to a mixt of nitric-acetic acids maintained below 0°. Cellobiose was abtd by saponification with Na ethylate of β-cellobiose octanitrate(Ref 4)

*Refs:* 1)Beil-not found 2)W.R.Ashford et al, CanJRes **24B**, 242(1946) 3)Ibid, **25B**, 155-8 (1947) & CA **41**, 4312(1947) 4)G.Fleury et al, MP **31**, 115-16(1949) & CA **46**, 1168(1952) 5) E.P.Swan & L.D.Hayward, CanJChem **34**, 856-62(1956)(Denitration of cellobiose octanitrate)

**Cellophane.** Registered trade name for the elastic, transparent, heat-resistant, water-and oil insol, gas-tight cellulose film obtd by pptn of viscose soln with Amm salts. It is used as a wrapper or protective package for fabricated articles(Refs 1 & 4). Manuf of cellophane is described in Ref 3

Use of cellophane in packaging of mortar increment chges was investigated at PicArsn (Ref 2). "Saran" coated cellaphane has not proven to be entirely satisfactory, but appeared that laminates ofpolyethylenewith cellophane would probably begreatlysuperior to any single film or coated film

*Refs:* 1)Hackh's(1944), 178 2)R.Bostwick, PATR **1621**(1946) 3)Kirk & Othmer **3**(1949), 280-91 4)CondChemDict(1961), 234

**Cellose.** Same as Cellobiose

**Cellosolve.** Registered trade name for mono- and dialkyl ethers of ethleneglycol and their derivs. The so-called "*Cellosolve" Solvent* is *Ethyleneglycol Monoethylether or 2-Ethoxyethanol*, $H_2C_2.O.CH_2.CH_2OH$; mw 90.12; col liq, d 0.9311 at 20/20°, fr p ca -70°, bp 135.1°, $n_D$ 1.406 at 25°, fl p 130°; miscible with w and hydrocarbons; can be prepd by heating ethylenechloride with ethanol & Na acetate, or by other methods; used as solvent for NC, natural & synthetic resins and for many other purposes (Refs 1-4)

There are also *Butyl "Cellosolve"*(qv), *"Cellosolve" Acetate*(Ethyleneglycol Monoethylether Acetate), $CH_3COO.CH_2CH_2.O.C_2H_5$; col liq, d 0.9748 at 20/20°, bp 156.4°; used as solvent for NC, oils and resins; *Methyl "Cellosolve"*(Ethyleneglycol Monomethylether or 2-Methoxyethanol), $H_3C.O.CH_2.CH_2OH$; col liq , d 0.9663 at 20/20°, bp 124.6°, $n_D$ 1.4021 at 20°, fl p 115°F(ca 46°); used as solvent for NC, cellulose acetate, synthetic resins and for purposes and *Methyl "Cellosolve" Acetate* (Ethyleneglycol Monomethylether Acetate), $CH_3COO.CH_2.CH_2.O.CH_3$; col liq, d 1.0067 at 20/20°, bp 145.1°, fl p 140°F(ca 60°); used as solvent for NC, cellulose acetate gums, resins, waxes, oil and for other purposes(Ref 1-4)

*Refs:* 1)Beil **1**, 467, (244), [518] & {2069} 2) Hackh's(1944), 178 3)Kirk & Othmer **7**(1951), 244-5(under Glycols) 4)CondChemDict(1961), 234 & 468

**Celloxylin.** Commercial term for NC's of low N content

**Cell-Pitch Lye.** It is a solid combustible material produced by evapn of spent waste liquid obtained from fermentation of sulfite-cellulose waste lyes(Ref 1). Was used in Germany as a fuel, as a binding agent and as an ingredient of AN explosives(Ref 2)

*Refs:* 1)H.B.Landmark, ChemZtg **39**, 98-9(1915) & JSCI **34**, 275(1915) 2)VKRP(Vereinigte Köln-Rottweiler Pulverfabriken), GerP 303980 (1917) & JSCI **41**, 199A(1922)

**Cellular Explosives of Low Density.** A water-stable, closed-cell, foamed-in-place explosive prepd by mixing a soln of HE(such as TNT, PETN, RDX, etc) with a resin [especially a mixt of polyesters of ethyleneglycol and

maleic anhydride and mono- or poly(methyl-methylacrylate)] and bubbling with air in a blowing chamber; then running the mixt into molds and curing. Alternatively 10-30% by vol of chem blowing agent, such as diazoaminabenzene or toluene diisocyanate is added and the mixt is foamed and molded at $\geq 120^{\circ}$. These expl foams are claimed to be useful in conjunction with high-density HE in floating mines, torpedoes, etc

*Ref:* H.J.Stark, USP 2845025(1958) & CA **52**, 17716(1958)

**Cellular Materials, Burning Characteristics of,** are discussed in US BurMines, Report of Investigation RI **4777**(1951), 16pp

**Cellulodine.** A mixt of NC with a small amt of cellulose was proposed by Marga in 1895. This mixt when treated with a volatile solvent for NC produced a jelly which was less viscous and easier to work than one contg only NC. The product was recommended for use in blank cartridges

*Refs:* Daniel(1902), 119

**Celluloid**(Zylonite or Xylonite). A proprietary product patented in 1870 by Hyatt Bros of Newark, NJ(Ref 5). Celluloid consists essentially of a solid soln of NC(with ca 11% N) and camphor(or its substitute), with or without a coloring matter. The product may be molded into differently shapedarticles(such astool handles, containers, combs, toys, discs, etc), using pressure and elevated temps. Props of typical Celluloids are: d 1.35-1.60, tensile strength 5000-10000psi, ignition temp 320-380°F(160-193°), molding temp 185-250°F(85-121°)(Ref 11). It is highly flammable and explodes when confined. Manuf of Celluloid is described in Refs 4,5 & 6; its toxicity is unknown(Ref 8). Its stability and tests are discussed in Ref 2

Some older foreign proplnts resembled, in their compns, Celluloid(see under Camphor). Use of Celluloid as bottom closing screw disc for time fuzes is described in Ref 3 and a smoke-producing device in Ref 7. Uses of Celluloid in some Brit ammo are discussed in conf Ref 10

The following two "Celluloid-Type" compns are used in US for military purposes (Ref 12): a)Composition A Cellulose Nitrate Plastic shall be manufd from NC(ca 11% N) ca 3parts, camphor ca 1part, urea 0.75 ± 0.05% of dry wt of NC and solvent in amt sufficient for processing. It is intended for use as wads and spacers in ammo b)Composition B Cellulose Nitrate Plastic shall be manufd from NC(not less than 11% N) 72 to 78 & camphor 28 to 22% with solvent sufficient for processing. In the dry product, used as discs of various thicknesses, the mineral ash content shall be not higher than 1%, and residual solvent from 0.83 to 5.0%, depending on thickness of the disc

The tests for these compns are described in Ref 12

*Refs:* 1)Daniel(1902), 119-25 1a)J.J.Trillat, CR **191**, 654-6(1930)(Structure of Celluloid) 2) Marshall **3**(1932), 215 3)V.H.Reed, PATR **607** (1935) 4)Thorpe **2**(1938), 443-56 5)Davis(1943), 257-8 6)Ullmann **5**(1954), 141-56 7)PYROFAG, GerP 953416(1956) & CA **53**, 10766(1959) [A smoke-producing device consisting of a burnable core(such as Celluloid) and a smoldering cover(such as paper impregnated with saltpeter)] 8)Sax(1957), 447 9)Röhm & Haas GmbH, GerP 964985(1957) & CA **53**, 22948(1959)(Celluloid-like substances obtained by plasticizing NC with dicyclopentadenones) 10) Directorate of Materials and Explosive Research and Development,GtBritain, Report Nos **PL/58/6** & **PL/58/7**, "Celluloid in Ammunition", Oct-Nov, 1958(Conf) 11)CondChemDict(1961), 235 12)US Military Specification MIL-C-1556(BuOrd), Cellulose Nitrate-Plastic(Celluloid or Pyroxyline Type)(for use in Ammunition)

**Celluloidine**(Poudre celluloïque). Smokeless proplnt patented by Turpin in 1888 was prepd by gelatinizing pulped NC with the least amt of a volatile solvent(such as ethyl acetate) and spreading the resulting paste, in a thin layer, on a large plate placed in a drier. Then the nearly dry thick sheet was removed, passed thru rolls and cut into small cubes

*Refs:* 1)Cundill(1889) in MP **6**, 107(under Turpin) 2)Daniel(1902), 125

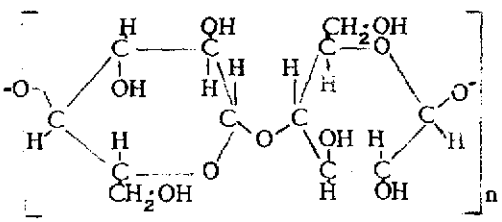
**Cellulosa.** The name given by C.G.Björkmann to the product obtained by nitration of 3parts of pea flour with mixed acid consisting of 10ps $H_2SO_4$ & 5ps $HNO_3$. This product was used in so-called Björkmann Explosives(qv)

*Ref:* Daniel(1902), 72(two bottom lines) & 125

## CELLULOSE AND DERIVATIVES

**Cellulose,** $(C_6H_{10}O_5)_n$; mw $(162.14)_x$, d 1.27-1.61; a white, polysaccharide occurring in all vegetable tissues & fibers. Its fundamental

composition corresponds to that of glucose anhydride. The cellulose molecule may be represented as a polymer of glucose-residue units linked in a chain:



The exact length of the cellulose molecule is not known but it is variable and very large. Cellulose threads possess micellar structure and consist(according to x-ray diagrams) of numerous rod-like crystallites, which are oriented with their long axis parallel to the thread axis, forming a fiber

Almost pure cellulose is found in pith, absorbent cotton & in some filter papers. Pure cellulose is most readily obtd from cotton by treating it with dil alkalies & acids and thoroughly washing with water. Another source of cellulose is wood(mostly coniferous) which contains 50-60% cellulose; and straw(mostly cereal) which contains 30-40%. A common classification of celluloses is based on their solubilities in aq alkalies: If cellulose is treated with NaOH soln of ca 18% at 20°, it will swell and much of the material, which is of short chain length, will dissolve. The residue from this treatment is called *alpha cellulose.* When the soln of shorter chain lengths, called hemicellulose, is acidified, part will precipitate. This is called *beta cellulose.* The remainder of substance, soluble in water, is called *gamma cellulose* (Refs 20,54 & 60)(See also Refs 4,5,26,28 & others listed)

Olsen(Ref 14a) described the prepn of refined wood pulp having alpha cellulose content up to 99%. This pulp approximated in its characteristics those of cotton linters, and was used for nitration to NC. Cellulose from reeds & other annual plants was investigated by the Société Française de la Cellulose(Ref 29) as a possible raw material for prepn of military grade NC. Eskridge(Ref 48) patented a process for the production of alpha cellulose from cottonhull fibers by digesting the fibers at 116° with an alkali soln contg 1.6% NaOH & other chemicals. A continous process for producing chemical-grade cotton from linters was reported by Hercules (Ref 50). What's unique about the Hercules' process is that digestion is carried out on moist cotton fibers rather than fibers slurried in liquor(Ref 51). Ardashev(Ref 11) made a study of the chemical delinting of cotton seed & of the industrial utilization of lint so obtained. Studies on the use of other materials as substitutes for cotton have been reported by Schwarz(Ref 3), Morin(Ref 6) and many other investigators

Cellulose is insol in w, alc, eth & all known simple org solvs. The best solv for it is cuprammonium hydroxide, $[Cu(NH_3)_4(OH)_2]$, also called Schweitzer's Reagent. It is also sol in a concd soln of Ca thiocyanate alone or in combination with formaldehyde. Other solvs & gelatinizers for cellulose include: zinc chloride (in 40% soln & on heating), basic beryllium perchlorate, 84% phosphoric acid, selenic acid, arsenic acid, sulfurous acid, 66% HBr, 70-75% HF, concd HI, chloral with pyridine, chloral hydrate in $H_2SO_4$, and inorg salts(such as NaCl) in concd solns & at high temps. Concd solns of NaOH at ca -10° only partially dissolve cellulose while the remainder is swelled & "mercerized". Sulfuric acid in concns of 60% & above dissolves cellulose, converting it into sulfates; when treated for only a short time with $H_2SO_4$, the cellulose is "parchmentized"(Ref 23,pp 150, 179,187 & Ref 44,p 362ff)

The physical & chemical props of cellulose have been detd & reported by a number of investigators. For this info the refs listed should be consulted

Since cellulose contains 3 active hydroxyl groups in each glucose anhydride unit, many substances react with it producing esters & other compds. These reactions are sometimes accompanied by destruction of the fibrous structure: *nitric acid,* in concns above 75%, forms NC suitable for the prepn of lacquers, artificial silk, celluloid & propellants(See also NC or Cellulose Nitrate); *acetic anhydride,* in the presence of $H_2SO_4$, converts cellulose into a mixt of di- and tri-acetates which are used for the prepn of acetate rayon & as moderants for some propInts; dilute *mineral acids* convert cellulose to "hydrocellulose" & finally into d-glucose; *oxidizing agents* such as chromates, bichromates, permanganates, bleaching substances, bromine water & others form a product called "hydrocellulose" & "oxycellulose"; concd *formic acid* produces cellulose formate (Ref 23,p 316); many *aliphatic & aromatic acids* produce esters of cellulose(Ref 23, 345-76); some *alkyl chlorides or sulfates* when heated with

cellulose in an autoclave produce ethers of cellulose (Ref 26,p 311 & Ref 23,p 377); various *nitrogen-contg* substances are used to prepare, by indirect methods, aminocellulose (Ref 23,p 423-38); *phenyl isocyanate* reacts with cellulose to produce the cellulose phenyl ester of carbamic acid($C_6H_5.NH.COO.C_6H_9O_4$); and a *viscose* soln, treated by the method of Lilienfeld, produces cellulose thiourethanes (Ref 23,p 440) [See also Cellulose Derivatives & Cellulose Nitrate(NC) described below]

*Uses.* Cellulose is the most important industrial org raw material in the world, and unlike mineral wealth, the supply is replenishable continously. It is the basis of the textile & paper-making industries. When nitrated,cellulose yields NC used in proplnts & expls, collodion, "celluloid", pyroxylin lacqures, and a variety of miscellaneous products

The requirements of the US Armed Forces for cellulose used in various military applications are given in the specifications listed as Ref 61

*Refs:* 1)Beil **31**, 446(Compd from sucrose) 2) M.Cunningham & C.Dorée, JCS **101** I, 497-512 (1912)(Action of ozone on cellulose) 3)R. Schwarz, MAF **1**, 229(1922); JCSI **38**, 602A(1919); ÖstChemZtg **22**, 50-2, 57-60(1919) & CA **13**, 3317(1919)(Cotton & its substitutes for manuf of NC) 3a)E.Worden, "Technology of Cellulose Esters", VanNostrand, NY, Vol I, Part I(1921) 4)C.Birtwell et al, JTextInst **14**, 305T(1923) & CA **18**, 171(1924)(Chemical analysis of cotton) 5) A.B.Corey & H.LeB.Gray, IEC **16**, 853, 1130 (1924) & CA **18**, 2805(1924); CA **19**, 575(1925) (Preparation of standard NC) 6)G.Morin, MP **22**, 57(1926)(Nitration cellulose derivatives) 7)A.W. Schorger, "The Chemistry of Cellulose and Wood", McGraw-Hill, NY(1926) 8)K.Hess, "Die Chemie der Zellulose und Ihrer Begleiter", Akademischen Verlag, Leipzig(1928) 9)L.Brissaud, MP **25**, 476-530(1932-33)(Degradation of cellulose by dil HCl) 10)H.Mark, "Physik und Chemie der Cellulose", Springer, Berlin(1932) 11)B.T. Ardashev, IEC **25**, 575-81(1933) 12)M.Battegay & L.Denivelle, "La Cellulose", Hermann, Paris (1934-35) 13)O.Faust, Edit,"Celluloseverbindungen", Springer, Berlin(1935) 14)Thorpe **2**(1938), 456ff 14a)F.Olsen, IEC **30**, 524(1938) 15)C.G.Schwalbe, "Die Chemie der Hölzer", Borntraeger, Berlin(1938) 16)E.Sutermeister, "Chemistry of Pulp and Paper Making", Wiley, NY (1941) 17)O.Eisenhut & E.Kuhn, AngChem **55**, 198-206(1942)(Microscopic investigation of native & artificial cellulose fibers) 17a)C.C.Furnas, Edit, "Rogers' Industrial Chemistry", Van Nostrand, NY(1942), 1441-56 18)R.B.Barns & C.J.Burton, IEC **35**, 120-5(1943)(Electron microscope and cellulose) 19)E.Ott, "Cellulose and Derivatives", Interscience, NY(1943) 20)Hackh's(1944), 178 21)N.Gralén, "Sedimentation and Diffusion Measurements on Cellulose and Cellulose Derivatives", Almqvist & Wiksells, Uppsala(1944) 22)E.Heuser, "The Chemistry of Cellulose", Wiley, NY(1944) 22a) Collective, MSCE **31**, 238(1944) & **33**, 107(1947) (Refining of linters) 23)J.T.Marsh & F.C.Wood, "An Introduction to the Chemistry of Cellulose", Chapman & Hall, London(1945) 24)R.N.Shreve, "The Chemical Process Industries", McGraw -Hill, NY, 1st edit(1945), pp 445,743,758 & 2nd edit(1956), pp 454, 783 25)P.H.Hermans, "Contribution to the Physics of Cellulose Fibres", Elsevier, NY(1946) 26)C.Dorée, "The Methods of Cellulose Chemistry", Chapman & Hall, London(1947) 27)J.M.Matthews et al, "Textile Fibers", Wiley, NY(1947), pp 99-450 28)The Svedberg, JPhCollChem **51**, 1-18(1947) (The cellulose molecule) 29)Société Française de la Cellulose, BritP 591072(1947) & CA **45**, 859(1951) 30)G.Champetier, "Dérivés Cellulosiques", Dunod, Paris(1947), 1-37 31) L.Brissaud, MSCE **33**, 75-98(1947)(Detn of pentosanes in plant materials & in pulp) 32) Collective, MSCE **33**, 99-106(1947)(Refining of pulp from wood) 33)G.Petitpas, MSCE **34**, 125 (1948)(Reaction of cellulose with alkalies) 34) T.Petitpas, MSCE **34**, 139(1948)(Variation of structure of cellulose in alk solns) 35)A. Bréguet et al, MSCE **34**,149,153(1948) (Absorption of NaOH by native cellulose & by regenerated viscose cellulose) 36)E.Calvet, MSCE **34**, 163-77(1948)(Mercerization of cellulose by NaOH) 37)J.Chastaignet, MSCE **34**, 255 (1948)(Extraction from wood by org solvs) 38) A.Roudier, MSCE **34**, 263(1948)(Extraction of cellulose from wood by org solvs) 39)A. Roudier, MSCE **34**, 273(1948)(Refining of cellulose) 40)K.Tamaru, JChemSocJapan **69**, 20-2(1948) & CA **46**, 8849(1952); BullChemSoc Japan **24**, 164-8(1951) & CA **47**, 305(1953) (Combustion of cellulose in presence of inorg salts) 41)Kirk & Othmer **3**(1949), 342-56 & **4** (1949), 563 42)P.H.Hermans, "Physics and Chemistry of Cellulose Fibers", Elsevier, NY (1949) 43)O.Pfeiffer & D.Krügger, "Beiträge zur Oxydation von Cellulose mit Stickstoffdioxyd", Verlag Chemie, Weinheim(1949) 44)Karrer (1950), 362ff 45)K.H.Meyer et al, Monatsh **81**,

151-4(1950) & CA **44**, 8639(1950)(Solution of cellulose in org solvs) 46)H.F.Mark & A.V. Tobolsky, "Physical Chemistry of High Polymer Systems", Interscience, NY, vol 2(1950) 47) R.S.Jessup & E.J.Prosen, JRNBS **44**, 387-93 (1950)(Heats of combustion & formation of cellulose & cellulose nitrate) 48)J.L.Eskridge, USP 2536045 & 6(1951) & CA **45**, 2668(1951) 49) L.E.Wise & E.C.Jahn, "Wood Chemistry", Reinhold, NY(1952) 50)Anon, ChemEngrg **61**, 116-8(May, 1954) 51)W.E.Segl, USP 2673690 (1954) & Official Gazette USPO **680**, No 5, 1279(30 Mar, 1954) 52E.Ott, H.M.Spurlin & M.W. Grafflin, "Cellulose and Cellulose Derivatives", Interscience, NY, Vol 5, Part 3(1955) 53)K. Ward, Jr, Edit, "The Chemistry and Chemical Technology of Cotton", Interscience, NY(1955), 782pp 54)B.B.Thomas, "The Production of Chemical Cellulose from Wood", JChemEduc **35**, 493(1958) 54a)J.Grant, "Cellulose Pulp", L.Hill, London(1958), 540pp 55)J.Honeyman, Edit, "Recent Advances in the Chemistry of Cellulose and Starch", Interscience, NY(1959), 358pp 56)J.A.Gascoigne & M.M.Gascoigne, "Biological Degradation of Cellulose", Butterworth, London(1960), pp 1-30 57)H. Staudinger, "Die Hochmolekularen Organischen Verbindungen, Kautschuk und Cellulose", Springer, Berlin(1960) 58)Consultants Bureau Interprises Inc, "Soviet Research on the Swelling of Cellulose Materials, 1949-1956", English Translation, NY(1960) 59)J.P.Casey, "Pulp and Paper", Interscience, NY, Vols 1-3 (1960-61) 60)ConChemDict(1961), 235 61) USSpecifications **MIL-C-206**(Cotton cellulose for use in expl); **MIL-C-216** [Wood pulp(sulfite) cellulose for use in expls]; and **MIL-C-677** (Cellulose, regenerated, strip for use in primer vent seals of small arms ammo)

**Cellulose Derivatives** [Except Cellulose Nitrate (NC)]. Cellulose, as a polyhydroxy alcohol, offers the possibility of reacting with many substances to produce a variety of compds. The course of the reaction and props of the derivs depend, to some extent, on the condition of the original cellulose. It may have been modified by hydrolysis, by oxidation, or by regeneration. Derivatives are prepd usually with the objective of obtg physical props, representing an improvement over cellulose itself. Therefore, treatments which result in only slightly modified cellulose, yielding no greatly changed physical props, are of comparative little interest to industry. It is also important that the deriv preserve the high molecular structure of the cellulose chain, otherwise the product will represent, not cellulose, but a degraded carbohydrate deriv (Ref 4). Spurlin(Ref 5) has considered the reaction of cellulose & its derivs in various reaction media: such as 1)homogeneous systems 2)two-phase systems in which cellulose is amorphous and 3)two-phase systems in which cellulose is partially crystalline(See also Ref 7 & others above)

Some reactions and derivs of cellulose are given under Cellulose(above). The derivs of interest in the expl industry and allied applications are included here:

*Cellulose Acetates or Acetyl Celluloses*(AC) are esters of cellulose & acetic acid, and are the most widely known org cellulose derivs; they are used extensively in industry under a variety of trade names. Olsen et al(Ref 3) proposed that AC's be used as deterrents in priming compns, and Preckel(Ref 8) patented their use as an inhibitor film on large-grain smokeless proplnts. There are also numerous applications of CA's in textiles & plastics used in ordnance. The specification requirements for AC's used in proplnts are given in MIL-C-20301. See also Vol 1,p A55-R under Acetyl Cellulose for addnl info on AC's

*Cellulose Acetate Butyrates,* wh flakes or granules, similar to cellulose acetate and similarly converted into plastic films, sheets & molded objects(Ref 9). See Specs MIL-C-5537A (1) & JAN-C-590

*Cellulose Acetate Nitrates.* See Nitroacetyl-celluloses, Vol 1,p A56-L

*Cellulose Acetonitrate,* $C_{12}H_{14}(NO_2)_2(COCH_3)_4$. This product & other acetonitrates, contg varying amts of $NO_2$ & Ac groups, were claimed to be prepd by Atsuki(Ref 1) by acetylating NC with acetic anhydride & glac AcOH in presence of $H_2SO_4$. The flammability of the product was much lower than that of NC, but its tendency to decompose spontaneously was the same as that of NC

*Cellulose, Aminated.* See Aminated Cellulose, Vol 1,p A172-L

*Cellulose, Aminated(Acetate Esters).* See Aminated Cellulose Acetate Esters, Vol 1,p A172-L

*Cellulose, Aminoethyl.* See Aminoethylcellulose, Vol 1,p A203

*Cellulose, Aminoethyl(Nitrate).* See Aminoethylcellulose Nitrate, Vol 1,p A204-L

*Cellulose, Aminoethyl(Perchlorate).* See

Aminoethylcellulose Perchlorate Vol 1,p A204-R

*Cellulose Benzoates* are esters of cellulose & benzoic acid. The mono- and di-benzoates were prepd by treating cellulose in alk soln with benzoyl chloride. Tri-benzoate was reported to have been prepd by the action of benzoyl chloride & pyridine on cellulose at 110-30° in the presence of nitrobenzene. The prod is sol in chlf & nitrobenz(Ref 6)

*Cellulose Benzoates(Nitrates).* Sendo & Kondo (Ref 2) treated cellulose monobenzoate at 18-20° with mixed acids of different percentage compn and obtd cellulose mononitrate- & dinitrate mononitrobenzoate. The expl props of these nitrates are similar to those of normal NC, but they are more stable, less hygro, less sol in eth-alc, and burn at a slower rate than NC

*Cellulose Nitrates.* See following item, discussed separately

*Cellulose Triacetate.* See Acetyl Cellulose, Vol 1,p A55-R

See also *Ethyl* and *Methyl Cellulose*

Refs: 1)K.Atsuki, JFacultyEngTokyoImpUniv **15**, 309-16(1915); CA **19**, 1626(1925) & SS **20**, 140(1925) 2)M.Sendo & J.Kondo, CelluloseInd (Tokyo) **6**, 150-5(1930) & CA **25**, 11668(1931) 3) F.Olsen et al, USP 2001212(1935) & CA **29**, 4586(1935) 4)C.J.Malm & C.R.Fordyce, "Cellulose Organic Acid Esters" in "Cellulose and Cellulose Derivatives", E.Ott, Edit, Interscience, NY(1943), 667ff 5)H.M. Spurlin, "Kinetics and Equilibria Involved in Cellulose Reactions", Ibid 6)Dorée(1947), 301-2 7)G.Champetier, "Dérivés Cellulosiques", Dunod, Paris(1947), 275pp 8)R.F.Prekel USP 2549005(1951) & CA **45**, 10590(1951) 8a)Faith, Keyes & Clark(1957), 242-6(Manuf of cellulose acetate) 8b)W.D.Paist, "Cellulosics", Reinhold, NY(1958)(Applications of chemical products from cellulose) 9)CondChemDict(1961), 236 10)US Spec **MIL-C-20301**(Cellulose acetate for use in proplnts)

**Cellulose and Its Esters(Except Cellulose Nitrate) Analytical Procedures.** Tests for cellulose used in industries other than manuf of expls & proplnts are described in Refs 1-6. Tests for cellulose acetate, cellulose acetate butyrate, ethylcellulose and methylcellulose are given in Ref 6, Methods D817, D871, D914 & D1347

US military requirements and tests for cotton intended for manuf of NC are as follows (Ref 7): a)The material shall be bleached cellulose prepd from cotton wastes or suitable short-fibered commercial cotton and shall be free from foreign matter of any kind. Cotton linters may be used when specified in the contract or order b)The material shall be prepd for nitrating by purifying and thoroughly washing with water c)Moisture(max 7.0%)- by loss of wt after drying at 105° d)Alkali sol matter(max 5.0%)- by extracting cellulose with 7.14% NaOH soln, washing the residue successively with water, alc & eth, drying at 105° and weighing e)Ether extractive matter(max 0.4%)- by extraction with ether, drying the residue at 105° and weighing f)Ash(max 0.5%)- by igniting a sample moistened with 70% nitric acid soln until the combustible matter has been consumed, cooling in a desiccator and weighing g)Viscosity(3 to 9 poises for Grade I cotton and 10 to 36 for Gde II)- by falling sphere method using soln of cellulose in cuprammonium h)Lime(max, trace)- by pptn of Ca ion with Amm oxalate soln i) Chlorides(max, trace)- by pptn of Cl ion with Ag nitrate soln j)Sulfates(max, trace)- by pptn of $SO_4$ ion with Ba chloride soln k)Hypochlorites (max, trace)-by KI soln(lt violet coloration) l)Absorbency- by rolling ca 1g sample into a ball and placing it lightly on the surface of 200ml of w in a 250ml beaker. The ball must sink below the surface within 3secs

US military requirements and tests for wood pulp(sulfite) intended for manuf of NC are as follows(Ref 8): a)The material shall be bleached sulfite pulp from coniferous wood which has been washed to remove the purifying chemicals and formed into sheets or laps suitable for fluffing or shredding and subsequent nitration. The material shall be free from foreign matter of any kind b)Moisture(max 10.0%)- by loss of wt after drying at 105° b)Weight- 0.525±0.125oz per sq ft per 0.01" thickness c)Thickness- $0.045^{+0.010"}_{-0.005"}$ d)Alpha-cellulose(min 95.0% for Grade A pulp and 90.0% for Gde B)- by treating a sample of cellulose with 17.5% NaOH soln, filtering, washing the residue, drying it at 105° and weighing e)Beta-cellulose(max 4% for Gde B) -by acidifying the filtrate of previous operation with glac AcOH, heating to coagulate the beta-cellulose, allowing ppt to settle, fitering, drying and weighing f)Gamma-cellulose(max 6.0% for Gde B)- by subtracting from 100 the sum of percentages of alpha- and beta-celluloses g) Alkali soluble matter(max 7.0% for Gde A & 15.0% for Gde B)- same procedure as for cotton h)Ether extractive matter(max 0.20% for Gde A & 0.40%

for Gde B)- same procedure as for cotton i)Ash (max 0.30% for Gde A & 0.50% for Gde B)- same procedure as for cotton j)Lime(max 0.05% for Gdes A or B)- by Amm oxalate soln k)Chlorides (max, trace)- by Ag nitrate soln l)Sulfates- by Ba chloride soln m)Hypochlorites(max, trace)- by KI soln(lt violet coloration in presence of trace of hypochlorites) n)Viscosity(8 to 17 poises)- by falling sphere method, using soln of cellulose in cuprammonium

US military requirements and tests for regenerated cellulose in strips ca 0.5" wide and ca 0.006" thick for use in primer vent seals for small arms ammo are described in Ref 9

US military requirements and tests for cellulose acetate, cellulose acetate butyrate and ethylcellulose are given in Refs 10, 11 & 12. There is no US military specification for methylcellulose

*Refs:* 1)Kast-Metz(1944), 22-53(Various tests for cellulose) 2)Dorée(1947), 10-39 42-72(Various tests for cellulose) 3)OrgAnalysis **1**(1953), 32 & 54-5(Some tests for cellulose) 4)Ott **5**, Pt 3 (1955), 1357-92(Various tests for cellulose) 5) OrgAnalysis **3**(1956), 479(Cellulose derivs, characterization) 6)ASTMStds(1961): Method **D1343**(Viscosity detn of cellulose derivs by falling ball method; **D1348**(Moisture detn in cellulose); **D1696**(Soly of cell in NaOH solns); **D1795**(Detn of intrinsic viscosity of cell dissolved in cuprammonium hydroxide soln by employing a capillary-type viscometer); **D1915** (Chromatographic analysis of chemically refined cellulose); **D817**(Tests for cellulose acetate butyrate); **D871**(Tests for cellulose acetate); **D914**(Tests for ethylcellulose); **D1347**(Tests for methylcellulose) 7)US Joint Army-Navy Specification JAN-C-206; Cellulose, Cotton(For Use in Explosives) 8)JAN-C-216; Cellulose, Wood pulp(For Use in Explosives) 9)JAN-C-677; Cellulose, Regenerated Strip(For Use in Ammunition) 10)US Military Specification MIL-C-20301, Cellulose Acetate(For Use in Propellants) 11) MIL-C-5537A(1), Cellulose Acetate Butyrate(For Use in the Manufacture of Organic Protective Coatings) 12)MIL-E-10853B(Ethylcellulose)

**CELLULOSE NITRATES or NITROCELLULOSES (NC's)**(called Nitrocellulose, Coton-poudre or Pyroxyline in Fr; Nitrozellulose in Ger; Nitrocellulosa in Ital; Nitrokletchatka, Piroksilin or Nitrotsellulosa in Rus; Nitrocelulosa or Piroxilina in Span; and Shōkamen in Jap)(See addl foreign names under specific types of NC).

Nitrocellulose(NC), more properly called "cellulose nitrate", is the oldest deriv of cellulose and the only inorg ester which has attained coml importance. Assuming a $C_6H_{10}O_5$ unit for cellulose,any NC may be written as $C_6H_7(OH)_x(ONO_2)_y$,where x+y=3. If for theoretical purposes the average number(y) of nitrate groupings for $C_6$ unit is required, it can be calcd from the relation:

$$y = \frac{162N}{1400\text{-}45N}$$, where N is percentage of nitrogen found on analysis. Thus a product contg on the average one nitrate grouping per $C_6$ will contain 6.76%N, two groupings 11.11%N and three groupings 14.14%N(Ref 59,p 233 & Ref 73a, pp 25-6)

With the exception of trinitrocellulose, however, the above NC's do not represent stoichiometric compds, since no homogeneous reaction product composed of a single individual mono-or dinitrocellulose has been obtained. The nitrate groups are distributed along the entire length of the cellulose chain according to the laws of chance and the reactivity of hydroxyl groups. Depending on the conditions of esterification, a NC of any desired N content may be obtained. The name "cellulose nitrate", or "nitrocellulose", therefore does not refer to a single stoichiometric compd, but it is a generic term denoting a family of compds(Ref 73a, p 26)

In older literature, especially the European, before the polymetric nature of cellulose was definitely established, its unit was assumed to be $C_{24}H_{28}O_8(OH)_{12}$ and its nitrated products were called dodecanitrate, endecanitrate etc. Since these terms are still found in some literature, their meaning is given in the following table:

| Cellulose | Formula | Molecular Weight | Nitrogen,% | NO per 1 g NC, in cc |
|---|---|---|---|---|
| Dodecanitrate | $C_{24}H_{28}O_8(ONO_2)_{12}$ | 1188.56 | 14.14 | — |
| Endecanitrate | $C_{24}H_{29}O_9(ONO_2)_{11}$ | 1143.56 | 13.47 | 214 |
| Decanitrate | $C_{24}H_{30}O_{10}(ONO_2)_{10}$ | 1098.56 | 12.75 | 203 |
| Enneanitrate | $C_{24}H_{31}O_{11}(ONO_2)_9$ | 1053.56 | 11.96 | 190 |
| Octanitrate | $C_{24}H_{32}O_{12}(ONO_2)_8$ | 1008.56 | 11.11 | 178 |
| Heptanitrate | $C_{24}H_{33}O_{13}(ONO_2)_7$ | 963.56 | 10.18 | 162 |
| Hexanitrate | $C_{24}H_{34}O_{14}(ONO_2)_6$ | 918.56 | 9.15 | 146 |
| Pentanitrate | $C_{24}H_{35}O_{15}(ONO_2)_5$ | 873.56 | 8.02 | 128 |
| Tetranitrate | $C_{24}H_{36}O_{16}(ONO_2)_4$ | 828.56 | 6.76 | 108 |

(See also Ref 51,p 367)

As the nitration of cellulose is a heterogeneous reaction involving irregular esterification of some or all OH groups, the attributing of definite formula to products of nitration is not necessarily valid. The N content of any particular NC largely defines its soly & other props, and consequently its industrial application. A summary of the types of NC's used in industry is as follows(Refs 43 & 59)

| Nitrogen, % | Solvents | Uses |
|---|---|---|
| 10.7-11.2 | Alcohol | Celluloid plastics; laquers |
| 11.2-11.7 | Methanol; eth-alc; acetone ethyl-, buty- or amyl acetates; methyl -ethyl ketone | Photogr films, laquers & nitrate rayon |
| 11.8-12.3 | Same as above; insoluble in alcohol | Gelatinous expls; films; laquers; artifical leather |
| 12.4-13.5 | Acetone; partially sol in other solvents | Propellants & explosives |

*Historical* (Ref 3). The history of modern expls began with the discovery of NG & NC. At about the time that A.Sobrero first prepd NG, during 1845-47, C.F.Schönbeim at Basel and R.Böttger at Frankfort-on-the-Main independently nitrated cotton; they perceived the possibilities of the prod and later cooperated to exploit its use in expls. Earlier in 1833, Braconnot had nitrated starch; and in 1838 T.J.Pelouze continuing the experiments of Braconnot, also nitrated paper, cotton & various other materials but did not realize that he had prepd NC. With the announcement by Schönbeim in 1846, and in the same year by Böttger that guncotton had been prepd, the names of these two men soon became associated with the discovery & utilization of NC. However, the published literature, at that time, contains papers by several investigators on the nitration of cellulose, before the process of Schönbeim was known. Among these were paper by Dumas and Pelouze, and Prof Otto of Germany. Other names associated with the prepn of NC are those of Berzelius, Taylor, Dr Knopp of Leipzig, Teschemacher, Gladstone, Crum, von Lenk of Austria, and others up to 1852(Ref 44)

A patent by Tompkins in England mentions, in 1862, the use of "pulped guncotton" but makes no claim to invention of the pulping process. It was Abel's patent of 1865 on "Improvements in the Preparation and Treatment of Guncotton" that claimed the process of converting NC into a pulp in the same manner as practiced in making paper. Abel showed thru his process of pulping & pressing NC into sheets, discs, cylinder & other forms, and thru further researches that the stability of NC was greatly improved. Shortly, thereafter, E.A.Brown, asst to Abel, discovered that dry compressed NC could be made to detonate violently by a MF detonator such as Nobel had used for NG. Then, a further discovery was made that wet, compressed NC could be exploded by a small quantity of dry NC [principle of Booster(qv)]. Thus large blocks of wet NC could be used with comparative safety and the manuf & use of NC were thereby established(Ref 44)

The next major step in the history of NC was the development of celluloid(1870) the first synthetic plastic. This was followed by development of the NC lacquer industry which, following WWI, expanded greatly(Ref 43)

**Properties of NC's.** See under Collodion Cotton, Pyrocellulose, Blend and Guncotton

**Preparation of NC's.** Cotton, one of the purest forms in which cellulose occurs in nature, had been used(up to WWII) as the chief source for the prepn of NC. Efforts have been made also to find other sources of cellulose, such as wood & other plants, suitable for nitration. The present major sources of nitration grade cellulose are sulfite & sulfate wood pulps. Although $HNO_3$, in both liq & vapor form, and mixts of $HNO_3$ with a variety of other chemicals have been used experimentaly to nitrate cellulose, the industry to-day and for over a century still employs $HNO_3$-$H_2SO_4$ acids as nitrating agent. In contrast to other reactions, in which cellulose dissolves & its original fibrous structure is lost, nitration is effected with retention of its fibrous structure, except that some swelling of fibers might take place

For explanation of the process of nitration two theories were advanced. Accdg to the 1st of these, the reaction proceeds in topochemical fashion, whereby the nitrating reagent diffuses progressively from the outside to the interior of the fiber, so that the chains on the surface are nitrated first. Accdg to the 2nd theory, the nitrating reagent penetrates uniformly in all parts of the cellulose fiber, and the reaction proceeds quickly thruout the whole micellar system in

permutoidal manner(Ref 73a,pp 26-9 & Ref 74,pp 730-7). Accd to Miles & Craik(Ref 9a) the nitration of NC of less than 12.5%N is a topochemical reaction whereas above this N content the reaction is permutoidal

The extent or degree of nitration of cellulose is expressed by the nitrogen content, except in France & some other Latin countries, where the degree of nitration is expressed as cc's of NO evolved in a nitrometer and measured under std conditions, per 1g of NC. Each 0.1cc of NO corresponds to ca 0.0063%, or each percent of NO times 15.96 equals number of cc of NO(Ref 44,p 258; Ref 50, table 3 & Ref 51,p 367)

It is possible to prep NC's covering the entire range of N content,however,the products normally prepd(for military applications) fall in the range ca 10.7 to 14% as shown in table above. The products with N to ca 12.2%N are known as "Collodion Cotton" or "Pyroxylin". Those with N 12.6-12.7% as "Pyrocellulose", "Pyro" or "Pyrocotton"; those with N 12.15 -12.25 as "Blend" or "Blended NC"; those with 13.35-13.45% as "Guncotton" and those with N content ca 14% as "High Nitrogen NC". The prepn, props and uses of various NC's in proplnts & expls are discussed separately below *Laboratory Procedure Used at Picatinny Arsenal* (Ref 79). Second cut cotton linters or wood pulp previously dried to a moisture content of less than 0.5%, are nitrated by immersion in mixed acid(MA):

Ratio of MA to cotton 55to 1
Composition of MA(approx)
a)for 12.6%N $H_2SO_4/HNO_3/H_2O$ 63.5/21/15.5%
b)for 13.4%N $H_2SO_4/HNO_3/H_2O$ 68/22/10%
Temp of acid at start 34°C
Time of nitration 24 minutes

During nitration the mixt is stirred occasionally to keep the acid homogeneous. The mixt is then filtered on a Büchner funnel for ca 3 mins and rapidly drowned, accompanied by strong hand stirring, in at least 50 vols of cold w, contg ice. After the NC is settled, most of the w is decanted & fresh w is added. The NC-w mixt is boiled & the acidity adjusted to 0.25 to 0.50% as $H_2SO_4$. This "sour boil" is continued for at least 24hrs for Pyrocellulose and at least 60 hrs for Guncotton. Addl boiling with changes of w are made in accordance with Specification MIL-N-244A

The next operation is "pulping" of NC in a lab Holland type paper beater. Enough Na carbonate is added to keep the reaction faintly alk to phenolphthalein. Pulping is continued to the desired fineness. "Poaching" is conducted by washing NC from the beater, filtering the mixt and boiling for 4hrs with fresh w while stirring mechanically. From time to time a little $Na_2CO_3$ soln is added to maintain the mixt sl alk to phenolphthalein. According to the Spec, the total boiling treatment with poaching is as follows:

4 hrs boiling with or without $Na_2CO_3$
2 hrs boiling without $Na_2CO_3$
1 hr boiling without $Na_2CO_3$
1 hr boiling without $Na_2CO_3$

Each boil is followed by settling of NC & change of w. Finally "washing" of NC is conducted with a min of two washes accompanied by mechanical agitation. If a sample taken after the w washes gives a min of 35 minutes in the 65.5°C Heat Test & 30 minutes in the 134.5°C Heat Test, the NC is considered satisfactorily stabilized. Otherwise addl washes should be given the NC

*Industrial Manufacture of NC*(Ref 75). For military use the ind manuf of NC in the USA is carried out by the mechanical dipper process (DuPont) which has displaced other hazardous processes. About 32 lbs of dried cotton linters or wood pulp cellulose is added to a chge of ca 1500 lbs mixed acid at a temp of 30°C. The nitrator is equipped with paddles, so designed that the cellulose is immediately drawn below the surface of the acid. Since the nitration reaction is exothermic, the temp is kept from rising above 34°. Addn of cellulose to the acid requires about 4 mins; nitration, with agitation of the mixt, requires 20 mins total time. The slurry is then discharged thru a bottom valve into a centrifuge, where most of the spent acid is removed. This acid-wet crude NC then is forked thru an opening in the bottom of the wringer into a drowning basin, where it is rapidly submerged by a heavy stream of w. It is now ready for the necessary purification process

The mixed acid used in the nitration of cellulose has a compn dependent upon the type of cellulose nitrated, the degree of nitration desired, and the season of the year. During warm weather, it is necessary that the $HNO_3$ content be sl greater than during winter, because of a tendency toward denitration of the mixed acid during warm weather. Variations in mixed

acid compns are used also in order to obt products having different solubility & viscosity characteristics. Typical compns of mixed acids are shown below:

**Composition of Mixed Acid for Nitrating Cellulose**

| Composition, % | For Pyrocellulose from: Cotton Linters | Wood pulp Cellulose | For Guncotton from: Cotton Linters | Wood pulp Cellulose |
|---|---|---|---|---|
| Sulfuric acid | 59.2 | 57.0 | 60.5 | 59.5 |
| Nitric acid | 21.5 | 23.5 | 24.5 | 28.5 |
| Nitrosylsulfuric acid | 3.5 | 4.4 | 4.0 | 3.0 |
| Water | 15.8 | 15.1 | 11.0 | 9.0 |

Removal of impurities, originally present or produced by side reactions during nitration of cellulose, is accomplished by lengthy hydrolysis under acid conditions, beating, poaching & washing operations. The acid hydrolysis, termed "sour boil", is carried out by treating the crude NC with boiling w contg 0.025-0.50% acid, calcd as $H_2SO_4$. Pyroxylin & Pyrocellulose are subjected to 40 hrs of boiling treatment, with 3 changes of w; Guncotton is subjected to 60 hrs of boiling treatment, followed by two 5-hr boiling treatments, with 3 changes of w. Beating, poaching & washing operation are carried out similar to the Spec procedure given under Laboratory Procedure

**Military Grades of NC.** The product produced by the above nitration & purification process is of max stability. It is generally v sl alk and contains less than 0.01% cellulose sulfate, which is unstable to heat & moisture. The great care taken in the purification of NC is necessary since propellants made from NC contg even small amts of unstable impurities deteriorate rapidly. The US military grades of NC are as follows:

| | Nitrocellulose | Nitrogen Content |
|---|---|---|
| Grade A | Pyrocellulose | |
| Type I | | 12.60±0.10%N |
| Type II | | 12.60±0.15%N |
| Grade B | Guncotton | 13.35%N (minimum) |
| Grade C | Blend | |
| Type I | | 13.15%±0.05%N |
| Type II | | 13.25%±0.05%N |
| Grade D | Pyroxylin | 12.20±0.10%N |
| Grade E | | 12.00±0.10%N |

In addn to requirements with respect to nitrogen content, NC must comply with requirements of the 65.5°KI & 134.5°Heat Tests. Grades A & D NC must not be less than 99% sol in eth-alc mixt. Grade A(Type I), Gd C & Gd D NC must contain not more than 0.4% ash and not more than 0.4% material insol in acet. Other requirements such as fineness & viscosity may also be specified. Explosive & other props of military grade NC are discussed under individual types, below

*Uses.* NC isused in single-base, smokeless propellants(NC & non-expl ingredients); double -base, smokeless proplnts(NC & NG); triple -base, smokeless proplnts(NC, NG & nitroguanidine); and in dynamites. Commercially NC is used in pharmaceuticals, lacquers, and photographic products(Ref 80)(For more detailed info on NC's, see various types of NC listed in Table and discussed separately, next page)

**Collodion Cotton or Pyroxylin**(called Pyroxyline or Collodion in Fr; Kollodiumwolle in Ger; Collodio or Pirossilina in Ital; Kolloksilin or Piroksilin in Rus; and Colodio or Piroxilina in Span)(Grade D NC, according to US Military Spec MIL-N-244A) NC contg 11 to 12% N, which corresponds to a mixt of "octanitro- and enneanitrocelluloses", $C_{24}H_{32}O_{12}(ONO_2)_8$ to $C_{24}H_{31}O_{11}(ONO_2)_9$, according to earlier nomenclature; lt-yel matted filaments or pale yel, syrupy liq when dissolved in eth-alc(3:1); very flammable & dangerous, fl p <80°F; decompd by light; sol in eth-alc, acet or glacial AcOH, and is pptd from soln by w; when exposed in thin layers of soln, its solv evaporates leaving a tough, colorless film(Ref 81). When subjected to the action of boiling water for 10 days, it is hydrolyzed to the extent of 1.71% (available $HNO_3$ liberated)(Ref 75)

Pyroxylin was first prepd, in 1838, by Pelouze and later by other investigators who nitrated paper, linen & cotton by the action of $HNO_3$(Ref 44). Its prepn by nitrating tissue paper using mixed acid is described by Worden (Ref 7)

Material used for the manuf of celluloid contains 11.0 to 11.2%N, while that used in *Blasting Explosives*(qv) has a N content of 11.5-12%. Military Pyroxylin contains 12.2±0.10%N(Ref 75)

Two kinds of NC's were used in France during WWI: *Coton-Poudre No 1*($CP_1$), insol in eth-alc & contg ca 13%N; and *Coton-Poudre*

## Table VIII

### Thermochemical Properties of Nitrocellulose (Compiled from Information Supplied by E.Costa & R.

| Nitrocellulose(NC) | Empirical Formula | Mol Wt. | % N | OB to CO, % | OB to $CO_2$, % | Density, g/cc | Heat of Combstn (at const vol), cal/mole (6) | Heat of Expln(at const vol), cal/g (7) | Gas Volume, moles/g (8) | Mean Heat Capacity, cal/g/deg (9) | Covolume in $^3$/lb(10) | Relativ Energy, cal/g(1 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Collodion Cotton(1) | $C_6H_8N_2O_9$ | 252 | 11.1 | -6.3 | -44.5 | 1.653 | 657000 | 734 | 0.04390 | 0.3545 | 29.61 | -27 |
| Collodion Cotton(1) | $C_6H_{7.68}N_{2.32}O_{9.645}$ | 267 | 12.2 | -1.2 | -37.1 | 1.653 | — | 895 | 0.04129 | 0.3478 | 28.51 | +155 |
| Pyrocellulose(2) | $C_6H_{7.55}N_{2.45}O_{9.90}$ | 272 | 12.6 | +0.7 | -34.6 | 1.655 | 651800 | 941 | 0.04041 | 0.3454 | 28.11 | 183 |
| Blend(3) | $C_6H_{7.365}N_{2.67}O_{10.27}$ | 281 | 13.15 | 3.4 | -30.8 | 1.656 | 651700 | 1024 | 0.03920 | 0.3421 | 27.56 | 268.4 |
| Blend(3) | $C_6H_{7.33}N_{2.67}O_{10.34}$ | 282 | 13.25 | 3.8 | -30.2 | 1.656 | 650000 | 1034 | 0.03898 | 0.3415 | 27.46 | 279 |
| Guncotton(4) | $C_6H_{7.30}N_{2.71}O_{10.41}$ | 284 | 13.35 | 4.3 | -29.5 | 1.656 | — | 1040 | 0.03876 | 0.3409 | 27.36 | 291 |
| Guncotton(4) | $C_6H_{7.26}N_{2.74}O_{10.48}$ | 285 | 13.45 | 4.8 | -28.9 | 1.657 | 649000 | 1061 | 0.03854 | 0.3403 | 27.26 | 305 |
| High-Nitrogen NC(5) | $C_6H_7N_3O_{11}$ | 297 | 14.14 | 8.1 | -24.2 | 1.659 | 647000 | 1160 | 0.03704 | 0.3362 | 26.57 | 407 |

(1)Collodion cottons are also called "pyroxylins". NC's contg 11.0-11.2% N are used in manuf of celluloid, NC's contg 11.5-12.0% are used in manuf of some blasting expls and NC contg 12.2±0.1% N is used for military purposes. All pyroxylins are sol in ether-ethanol mixts and partially sol in ethanol (2)Pyrocellulose, or simply "pyro" used for military purposes, contains 12.6±0.1% N. It is completely sol in 2:1-ether-ethanol (3)Blends are usually obtained by blending "pyro" with guncotton, but they can also be prepd by direct nitration of cellulose with acids intermediate in strength betw-those used in prepn of pyro and of guncotton (4)Guncotton used for military purposes contains 13.35-13.45% N. Its solubility in 2:1-ether-ethanol is 6 to 10% (5)High nitrogen NC can be prepd by nitration of cellulose with mixt of nitric-acetic acid with acetic anhydride or by other methods. It is sol in acetone, as are collodion cotton, blend, pyro and guncotton (6)Heat of Combustion,(-E), is taken from NBSJR 44, 387-93(1950) (7)Heat of Explosion, Q, is calcd from the formula $Q=\frac{(-E)-67421(2C+0.5H-O)}{\text{Mol Wt}}$ cal/g (8)Gas Volume, n, is calcd from the formula $n=\frac{C+0.5H+0.5N}{\text{Mol Wt}}$ (9)Mean Heat Capacity, $C_v$, is calcd from the formula $C_v=\frac{1.62C+3.265H+3.384N+5.193O}{\text{Mol Wt}}$ (10)Covolume, $\eta_i$, is calcd from the formula $\eta_i=0.9\frac{(29.2C+7.0H+17.0N+3.8O)}{\text{Mol Wt}}$ cm$^3$/g; by multiplying it by factor 27.7, the covolume is obtained in in$^3$/lb (11)Relative Energy in the Gas, E, is calcd from the formula $E=\frac{(-E)-132771C-40026H-6724N+51819O}{\text{Mol Wt}}$

*No 2*($CP_2$), sol in eth-alc & contg ca 12%N. A mixt of $CP_1$ & $CP_2$, colloided with eth-alc, was used to make *Poudre B*(See B Poudre). Either $CP_1$ or $CP_2$ with NG was used to make *Ballistite* (qv); and both of them, with NG and non-volatile solvs, were used to make *Attenuated Ballistite* (See Vol I,p A506-L). Before WWII, *Poudres SD* (sans dissolvants or solventess powders) were prepd in France. These pdrs consisted of NC gelatinized with NG and without a vol solv. The so-called $CP_2$SD(which stands for NC contg 11.6-11.7%N, without solvent)was used in some of these proplnts. The designation $CP_3$, sometimes found in Fr literature, means NC with a N content to ca 11.5%(Refs 8,14,22 & 68)

Italian collodion cotton and its specifications are described by Molina(Ref 9), Mangini (Ref 60), Giua(Ref 62), Belgrano(Ref 70) & in Ref 69

According to Pérez Ara(Ref 51) & other sources, Spainish NC corresponding to Amer Collodion Cotton (Pyroxylin) is called *Colodion* $CP_2$ or *Algodón Colodion* and consists of a mixt of octo- and nononitrocellulose. Its N is 11-12% and d 1/653; NO evolved was 180-190cc/g of NC [See also Sancho(Ref 39)]

Stettbacher(Ref 61) reported that the compn & prepn of Swiss NC proplnts were similar to Fr *Poudre B*. They differed only in form and size of grains. These proplnts were prepd by mixing in a "Knettmachine"(kneading machine), and in the presence of eth-alc, 80 *Guncotton*(13-13.4%N) and 20% *Collodion Cotton* (11.7-12.2%N) to which was added 1-1.5% DPhA. The gelatinized mass was worked to the desired shape & size of grains, and the vol sol evaporated by drying. These proplnts were manufd by "Die Eidgenössische(Staatliche) Pulverfabrik in Wimms(Bern)(See Ref 27)

**Pyrocellulose, Pyro or Pyrocotton** [called Coton-poudre or CP in Fr(may be considered as a mixt of Coton-poudre No 1 or $CP_1$(13%N) and of Coton-poudre No 2 or $CP_2$(12%N); Schiessbaumwolle in Ger; Pirocollodione in Ital; Piroksilin No 2 or Pirokollodion in Russ; and Pirocelulosa in Span] [Grade A NC, according to US Military Spec MIL-N-244A(2)]. NC contg 12.6±0.15%N, which corresponds to "decanitrocellulose", $C_{24}H_{30}O_{10}(ONO_2)_{10}$, according to earlier nomenclature; mw 1098.56, N 12.75%, OB to $CO_2$ -35%; wh solid d 1.655 *Historical.* See under Cannon Propellants

Pyrocellulose is made by the laboratory & industrial procedures described under CELLULOSE NITRATES

Its properties are as follows: *Ballistic Potential,* $(Q_e^v)_g xV_i/1000=789$, $(Q_e^v)_c xV_c/1000=766$; *Brisance* by Sand Test, 45g sand crushed vs 48g for TNT; *Explosion Temperature,* 170° dec(5 sec); *Gas Volume* produced on explosion, detd(V) 743ml/g with $H_2O$ liq, detd($V_i$) 917ml/g with $H_2O$ gas, calcd ($V_c$) 904ml/g with $H_2O$ gas; *Heat of Combustion,* ($Q_c^p$) 2406cal/g at const press, ($Q_c^v$) 2415cal/g at const vol; *Heat of Explosion,* detd ($Q_e^v$) 942cal/g with $H_2O$ gas, $(Q_e^v)_g$ 860cal/g with $H_2O$ gas at const vol, calcd $(Q_e^v)_c$ 849cal/g at const vol; *Heat of Formation,* 615cal/g at const press; *Hydrolysis Test,* 249 hrs, forms 1.22% $HNO_3$; *Hygroscopicity,* at 30° and 90% RH, gains ca 3%; *Impact Sensitivity,* 2kg wt, PA App 3" for 5mg sample vs 14" for TNT, Bur of Mines App 8cm; *Solubility,* insol in w & eth, 99% dissolves in eth-alc(2:1), 63% dissolves in NeOH, 21% dissolves in ethyl nitroacetate, 11% dissolves in alc; sol in acet, ethyl acetate, methyl acetate, propylene oxide, nitromethane, nitroethane & in other solvs; *Stability* by 65.5°KI Test,minimum 35 mins and by 134.5° Heat Test minimum 30 mins; *Vapor Pressure* at 60° 0.0mmHg; *Volatility* at 60° 0.0% and *Water Produced on Explosion* 140g/kg of NC *Uses.* Pyrocellulose has been used since the Spanish-American War(1898) in cannon and small arms proplnts. Historical development of "Pyro" proplnts is described under Cannon Propellants(qv). The original US single-base proplnts consisted of Pyrocellulose colloided with ether-alc, but beginning ca 1909, there was added 0.5% DPhA to act as a stabilizer and this amt was later increased to 1%. This period also saw the introduction of the "water-dry process" which permitted manuf of proplnts in a fraction of the time reqd for the "air-dry process"(Ref 44)

Pyrocellulose proplnts were unduly hygro and gave bright flashes when fired from a cannon. However, this compn remained std until adoption of FNH(flashless-nonhygroscopic) and NH(nonhygroscopic) single-base proplnts ca 1930. Yet, pyrocellulose proplnts were manufd & used extensively by the US Navy during WWII (Ref 75,p 248)

To-day, in the manuf of NC propellants, there sometimes are used mixts of Pyrocellulose & *Guncotton*(qv), which are called *Blend or Blended Nitrocellulose*(qv). These mixts are

designed to have the desired solubility & viscosity characteristics, and a specified N content(See also under Cannon Propellants)

**Blend or Blended Nitrocellulose**(Grade C NC, according to US Military Spec MIL-N-244A). This NC prepd by blending 60-65% *Guncotton* (ca 13.4% N) with 40-35% *Pyrocotton*(ca 12.6% N). The resulting "blend" contains 13.15±0.05% N. Blended NC is used when it is desired to prep a single-base, smokeless proplnt of high ballistic potential using 2:1 eth-alc as solv. It is not possible to prep this kind of proplnt using straight guncotton because guncotton is only sl sol in 2:1 eth-al and therefore would not form a colloid. The Blend is sol in 2:1 eth-alc to the extent of 35-40% or ca the percentage of Pyrocellulose in it. The resulting colloid is quite suitable for the prepn of smokeless proplnts

Perparation of Blended NC is described under *Guncotton*(qv)

The props of the Blend are as follows: *Ballistic Potential*, $(Q_e^v)_g xV_i/1000=845$, $(Q_e^v)_c xV_c/1000=814$; *Brisance* by Sand Test, 48g sand crushed vs 48g for TNT; *Explosion Temperature*, 200° dec(5 sec); *Gas Volume* produced on explosion, detd(V) 720ml/g with $H_2O$ liq, detd(Vi) 893ml/g with $H_2O$ gas, calcd ($V_c$) 878ml/g with $H_2O$ gas; *Heat of Combustion*, ($Q_c^p$) 2338cal/g at const press, ($Q_c^v$) 2348cal/g at const vol; *Heat of Explosion*, detd ($Q_e^v$) 1027cal/g with $H_2O$ liq, $(Q_e^v)_g$ 946cal/g with $H_2O$ gas at const vol, calcd $(Q_e^v)_c$ 927cal/g with $H_2O$ gas at const vol; *Heat of Formation*, 576cal/g at const press; *Hydrolysis Test, 240* hrs, forms 1.1% $HNO_3$; *Hygroscopicity*, 30° and 90% RH, ca 2.5%; *Impact Sensitivity*, 2 kg wt, PA App 3" for 5mg vs 14" for TNT, Bur of Mines App 8cm; *Solubility*, insol in w & eth, sl sol in alc, 35-40% sol in 2:1 eth-alc, sol in acet, ethyl acetate & in many other org solvs; *Stability* in 65.5°KI Test, 35 min + , in 134.5° Heat Test, 30 minutes +; *Vapor Pressure* at 60°, 0.0mm Hg; *Viscosity* in 5% acet soln at 25°, ca 1.4 sec (for a steel ball 5/16" diam to fall a distance of 10"); *Volatility* at 60°, 0.0%; *Water* produced on explosion, 139g/kg NC

*Uses.* Blended NC is used in the manuf of single-base and double-base proplnts. Requirements of the US Armed Forces for NC's used in manufg proplnts are given in Specification MIL-N-244A(See also Cannon Propellant)

**Guncotton** [called Coton-poudre in Fr(may be considered as Coton-poudre No 1 or $CP_1$ nitrated to higher than 13%N); Schiessbaumwolle or Schiesswolle in Ger; Fulmicotone in Ital; Piroksilin No 1 in Rus; Algodón Fulminante or Fulmicotón in Span; and Menyaku in Jap)(Grade B NC, according to US Military Spec MIL-N -244A). NC contg 13.35% N minimum, which corresponds to "endecanitrocellulose", $C_{24}H_{29}O_9(ONO_2)_{11}$, according to earlier nomenclature; mw 1143.56, N 13.47%; OB to $CO_2$ -29%; wh solid, d 1.665; insol in eth-alc; sol in acet or in ethyl acetate

Guncotton is the military grade of NC contg the highest N content(ca 13.45%) possible to obtain by nitrating cellulose with mixed nitric-sulfuric acids. The reason is not definitely known, but in 1901 Cross, Bevan & Jenks introduced the theory that cellulose reacts partly, during nitration, with $H_2SO_4$ forming sulfuric esters. These esters, being very stable, prevent nitration beyond the "endeca" stage. If it is desired to prepare NC with higher than 13.45% N, it is necessary to use mixed acids which do not contain $H_2SO_4$ as an ingredient. Such acids can be:

a)mixt of 99% $HNO_3$ + acetic acid + acetic anhydride

b)mixt of 99% $HNO_3$ + phosphoric acid + phosphoric anhydride

c)mixt of 99% $HNO_3$ + nitrogen dioxide(See Refs 23, 32)

d)mixt of 99% $HNO_3$ + some anhyd salt readily absorbing water, such as $Ca(NO_3)_2$

e)$N_2O_5$ fumes obtd by distilling nitric acid (Refs 23,25,28,41) and

f)finally by renitrating Guncotton using either straight $HNO_3$ or $HNO_3$ combined with AcOH, $Ac_2O$ or an anhydrous salt

(See also under High Nitrogen Nitrocelluloses)

*Preparation of Guncotton.* Cellulose intended for the prepn of Guncotton can be of cotton linters or wood pulp. Cotton linters are usually received in 150-lb bales, while wood pulp cellulose is received in the form of sheets, about 4ft wide, rolled into bales weighing ca 700-lbs each. Before proceeding with nitration, cellulose must be pretreated

I. Pretreatment of Cellulose. The bale of cotton linters is fed into a "balebreaker" and then into a "cotton picker". The fluffed cotton is fed over a slow-moving, wire-mesh into a drier equipped with steam heated coils & fans. The temp of drier is maintained betw 105-110°

(220-230°F), and this operation reduces the moisture content of linters from 6-7% to ca 0.5%. The linters are then removed from the bin, weighed & transferred to the nitrating room

In the case of wood pulp, the pulp sheets are fed into a drier maintained at 110-115° (230-240°F) by hot air jets. During a drying time of ca 15 mins, the moisture content is reduced from 4-5% to ca 0.5%. The dried pulp sheets pass from the drier into a "shredder" where they are reduced to peices about 5mm in length

If the cellulose is intended to be stored, it should be kept in airtight containers due to its hygro nature

**II.** Nitration of Cellulose. The "DuPont Mechanical Dipper Process" is now used exclusively in the USA. A nitrating unit consists of four stainless steel nitrators which discharge into the same centrifugal wringer. Each nitrator is equipped with two vertical agitators revolving in opposite directions, imparting motion toward the center. These agitatiors consist of a series of vertical arms, placed in such a manner, that when in motion the cotton(or wood pulp) is quickly drawn beneath the surface of acid & away from the fume exhaust line

Typical compns of mixed acids, used in nitrating cellulose to Guncotton, are given under CELLULOSE NITRATES, Preparation of NC(Industrial Manufacture of NC). The crude Guncotton & spent acid are discharged from the nitrator into a centrifugal wringer which removes most of the acid. The spent acid is run into tanks where it can be used, after adjusting its compn, for nitrating cellulose to Pyrocotton or where it is fortified to the same strength as the original MA for re-use. The wet Guncotton is immediately immersed in water to await "stabilization" & "purification"

**III.** Stabilization of Guncotton. **A.** Sour Boil. Due to the fact that acids & other impurities are strongly adsorbed on the fibers of NC and, therefore, are hard to remove, the stabilization of Guncotton is a tedious & elaborate process. The preliminary or "sour boil" of crude Guncotton is carried out in large wooden(cypress) tubs equipped with ducts for heating & circulating water at a temp approx 100°. During the first two hrs, the acidity of the water is adjusted to 0.05-0.50%(calcd as $H_2SO_4$). After a boiling treatment of not less than 40-hrs and a fresh water change, then two separate 5-hr boils follow(each preceded by a fresh water change) for a total boiling time of 70hrs(See also Ref 16)

**B.** Pulping. Since cellulose fibers are not solid but tubular, having capillary channels running thru them, part of the impurities present in Guncotton are occluded in these channels and cannot be removed unless the fibers are cut into very short fragments. This operation is done in an apparatus called a "beater", similar to that employed in the paper industry. The action of the blades in the "beater" cuts the unpulped Guncotton to lengths of 1 mm or less. Large amts of water, maintained alkaline by addn of $Na_2CO_3$, are used during this operation of pulping NC. The satisfactorily pulped NC is transferred as a slurry to the "poaching" house

**IV.** Purification of Guncotton: **A.** Poaching. Preliminary boiling of crude NC reduces its acidity while the pulping operation mechanically breaks down the fibers into very small fragments. However, these operations do not remove the acidity entirely and it is necessary to subject the pulped NC to additional boiling in water. This operation is similar to that described under "Sour Boil" except that it is conducted in an alk medium(See also Ref 11). The water is boiled by injectining live steam into the poachers and the operations of boiling & change of water are conducted as described under CELLULOSE NITRATES, Preparation of NC(Laboratory Procedure) **B.** Washing. Following poaching, the NC is sufficiently washed with cold water(not less than two washings) under mechanical agitation, for ½hr intervals, to insure its compliance with US Spec MIL-N-244A

**V.** Screening. In order to obtain uniformity in proplnts & uniform ballistics in weapons, it is necessary to have NC of uniform props(such as N content, viscosity & etc). It is very difficult to achieve this uniformity among different batches of NC. Good results are obtd when portions of batches having high N content & high viscosity are blended with portions having low N content & low visocosity. The resulting mixts possess props intermediate betw those of the individual batches. This operation is done during screening. The slurry from several poaching tubs is fed thru a distributor arrangements which spreads the NC uniformly on a "Packer" screens. The screen, having slots 0.02 inches, is vibrated mechanically and the properly pulped NC is blended as it passes thru the screen into

collecting boxes. If it is desired to obtn Guncotton and not a Blended NC, the material goes from the screen directly to the wringers to remove the remaining water

**VI.** Blending. From the standpoint of "ballistic potential", it would be advantageous to use straight Guncotton in smokeless proplnts, but Guncotton is only sl sol in eth-alc, the mixt commonly used in the USA to colloid NC. Therefore, Blended NC(qv) which is sol in 2:1 eth-alc mixt to the extent of ca 40%, is preferred for single-base proplnts. In this operation 60-65% of Guncotton(13.4%N) is blended with 40-35% of Pyrocellulose (12.6%N). Each blending unit consists of two tubs, both equipped with propellor type agitatiors, interconnected in such a manner that the contents are kept in constant circulation. The receiving tub(or high tub) of a blending unit is filled with slurry from the screening operation so that the overflow discharges into the "low tub". When the latter tub becomes partly filled, a circulating pump is started and part of the slurry is returned from the "low" to the "high" tub. This operation continues for 6-7½ hrs, after which time a sample is tested for N content & solubility in 2:1 eth-alc. If satisfactory, the blended slurry is transferred to the "wringing house"

**VII.** Wringing. The transference of NC, from the time of nitration thru stabilization, purification & blending operations, is accompanied by large amts of water which must be removed, since water would interfere with the colloiding of NC by 2:1 eth-alc. This water from purified NC is removed by wringing & partly by displacement with alc. The wringer is a centrifugal machine with a perforated brass basket lined with a 24-mesh copper screen. The basket is geared to revolve at 950 rpm, which centrifugal action forces the water from the NC to a drain. The time of wringing is ca 7 mins. The wrung NC (moisture content ca 31%) is discharged into metallic, rustproof cans provided with tightly fitting covers. This final operation concludes the manuf of NC

The properties of Guncotton(13.45% N) are as follows: *Ballistic Potential,* $(Q_e^v)_g xVi/100=867$, *Brisance* by Sand Test, 49g sand crushed vs 48g for TNT; *Detonation Rate,* 7300m/sec at d 1.20g/cc; *Explosion Temperature,* 230° dec(5 sec); *Gas Volume* produced on explosion, detd(V) 712 ml/g with $H_2O$ liq, detd($V_i$) 883ml/g with $H_2O$ gas; *Heat of Combustion,* 2303cal/g at const vol; *Heat of Explosion,* detd ($Q_e^v$) 1063cal/g with $H_2O$ liq, $(Q_e^v)_g$ 982cal/g with $H_2O$ gas; *Heat of Formation,* 551cal/g at press; *Hygroscopicity,* 30° and 90% RH, ca 2%; *Impact Sensitivity,* 2 kg wt, PA App 3" for 5mg samples vs 14" for TNT, Bur of Mines App, 9cm; *Power* by Ballistic Mortar, 125% TNT; *Solubility,* insol in w & eth, v sl sol in alc, ca 10% sol in 2:1 eth-alc, sol in acet, ethyl acetate & other org solvs; *Stability* in 100° Heat Test, loses 0.3% 1st 48 hrs and 0.0% in 2nd 48 hrs, in 100° Vacuum Stability Test(5g sample) 1.5cc gas evolved; *Vapor Pressure* at 60°, 0.0 mm Hg; *Volatility* at 60°, 0.0%

*Uses.* Guncotton is used for the prepn of various flashless proplnts and in shrapnel shell compns as a flame carrier. It is also used in electric primers & in electically initiated destructors(Ref 55). When used alone it requires a solv such as acet; when used in "Blended NC", a 2:1 eth-alc solv may be used. The requirements of the US Armed Forces for Guncotton used in military applications are given in Specification MIL-N-244A

**High-Nitrogen Nitrocelluloses.** This term includes all NC's having a N content higher than that of ordinary Guncotton, or from 13.75% N to 14.14% N, the latter representing the theoretical limit. Such a NC would consist principally of "dodecanitrate", $C_{24}H_{28}O_8(ONO_2)_{12}$, according to earlier nomenclature; mw 1118.56, N 14.14%; OB to $CO_2$ -24%, d 1.67-1.70

In order to prepare a proplnt of higher ballistic potential than is possible with ordinary Guncotton, High-Nitrogen NC must be used. It has already been explained under Guncotton that it is impossible to prepare a NC having higher than 13.45% N by nitration of cellulose with mixed $HNO_3$-$H_2SO_4$ acids. For this reason, High-Nitrogen NC must be prepd by using other nitrating mixts, not contg $H_2SO_4$ as a dehydrating agent. Some products resulting from the use of these various nitrating mixts are as follows:

a)Nitration of wet Guncotton(25% $H_2O$) with a mixt of nitric acid + acetic acid + acetic anhydride(60:20:20 or 50:25:25) and a ratio of guncotton to acid of 1 to 50, yields NC of 14% N, of low viscosity & suitable for military use; nitration of cellulose by similar nitrating agents yields NC of 13.8% N(See Refs 17,18,20,21,35,

47,56)
b)Nitration of cellulose with a mixt of nitric acid + phosphoric acid + phosphoric anhydride(49:49:2) and a ratio of cellulose to acid of 1 to 50, yields NC of 13.8% N(Refs 2,10, 12,29,30,31,34,36). The viscosity of this NC is very high, but it can be reduced & the NC stabilized by heating it in an 85/15 glycerin -water mixt or in an aq soln of Amm nitrate, or ammonia as proposed by several investigators c)Nitration of cellulose with 99% $HNO_3$ in the presence of $NH_4NO_3$ (15-20%) or $KNO_3$(30%) yields NC of 13.8% N(Refs 21,35). The salts prevent hardening & contraction of cotton linters which occurs when $HNO_3$ is used alone(Ref 21); wet guncotton may be similarly nitrated d)Nitration of cellulose, in the shape of paper rolls, with $N_2O_5$ gas produced by heating concd $HNO_3$, yields NC of 14% N. This process of prepg high-nitrogen NC was developed by the Germans during WWII(See Refs 23,25,28,41)

The properties of 13.75% N NC are intermediate between those of Guncotton(13.45%N) & of 14% N NC

Following are the props of 14%N nitrocellulose: *Ballistic Potential,* $(Q_e^v)_g xV_i/1000=$ 904, $(Q_e^v)_c xV_c/1000=867$; *Brisance* by Sand Test, 52g sand crushed vs 48g for TNT; *Gas Volume* produced on explosion, detd(V) 688ml/g with $H_2O$ liq, detd($V_i$) 854ml/g with $H_2O$ gas, calcd ($V_c$) 838ml/g with $H_2O$ gas; *Heat of Combustion,* ($Q_c^p$) 2232cal/g at const press, ($Q_c^v$) 2242cal/g at const vol; *Heat of Explosion,* detd ($Q_e^v$) 1137 cal/g with $H_2O$ liq, $(Q_e^v)_g$ 1059 cal/g with $H_2O$ gas at const vol, calcd $(Q_e^v)_c$ 1051cal/g with $H_2O$ gas at const vol; *Heat of Formation,* 516cal/g at const press; *Hydrolysis Test,* 240 hrs, forms 1% $HNO_3$; *Hygroscopicity,* 30° and 90% RH, ca 1%; *Impact Sensitivity,* 2kg wt, P A App 3" for 5mg sample vs 14" for TNT, Bur of Mines App 8cm; *Solubility,* insol in w, eth, n-propyl alc & iso-propyl alc; 0.6 sol in ethanol, 1% sol in MeOH, 1.4% sol in 2:1 eth-alc, 20% sol in methyl acetate, 42% sol in nitromethane, 86% sol in 1-nitropropane, and 100% sol in acet, eth acetate, propylene oxide & amyl acetate; *Stability,* in 90°C Vacuum Stability Test, 1.46cc gas evolved; in 100° Test, $11^+$cc in 24 hrs; *Viscosity,* 5% acet soln at 25°, ca 2 sec(time reqd for a 5/16" diam steel ball to fall a distance of 10"); *Volatility,* at 60°, 0.0%; *Water* produced on explosion, 133g/kg NC

*Uses.* High-Nitrogen NC is used for the prepn of high-ballistic potential smokeless proplnts, using a solv other than eth-alc. For example, in a single-base proplnt contg 95 NC(14%N), 2.5 $Ba(NO_3)_2$, 1.5 $KNO_3$, 0.75 DPhA & 0.25% graphite, a vol solv of 70 acetone & 30% alc may be used, or a mixt of acet & eth. In prepg this proplnt, the water in wet NC is replaced in the usual manner by alc, and then acet is added to make the total amt of solv equal to 50% of the total wt of resulting proplnt. This solv mixt is removed by mild heating

In the prepn of a double-base proplnt contg 81.5 NC(14%N), 15.0NG, 1.5 $Ba(NO_3)_2$, 1.0 $KNO_3$, 0.75 DPhA & 0.25% graphite, the solv can be the same as above, or it may contain more alc(43/47 acetone/alcohol). Due to the presence of NG, which acts as a gelatinzer for NC, the total amt of vol solv may be as low as 35% of the total wt of the mixt
(See also Cannon Propellants, Propellants & others)
(This section was reviewed by Dr F.J.Masuelli of PicArsn)

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thermal decompn of NC) 230)P.Lhoste & O. Naud, MP **38**, 137-43(1956)(The level of nitration of industrial NC's) 231)L.Brissaud et al, MP **38**, 145-57(1956)(The beating of NC; comparison of Horn & Thorsen beaters and the measurement of specific surface of NC) 232)Y. Lacroix et al, MP **38**, 159-66(1956)(The beating of Guncotton) 233)K.Brimley, BritP 787411(1956) & CA **58**, 7704(1958)(Plasticized NC of high N content & low viscosity for prepn of plastic incendiary mixts) 234)K.T.Carolan & M.Chmura, PATR **2440**(1957)(Storage stability of NC plastics) 235)J.S.Musgrave & R.L.Trask, PATR **2444**(1957)(Effect of NC stabilization cycle on cycle on stable life of proplnts) 236)M.A. Millett,"Studies on the Thermal Decomposition of Cellulose Nitrate and Cellulose Nitrate Propellants," Forest Products Lab, Madison, Wisconsin(1957)(A literature survey from CA 1907-56) 237)M.A.Millett,"Stability Tests for Military Cellulose Nitrate and Cellulose Nitrate Propellants", FPL(1957)(A literature survey 1907-57) 238)M.A.Millett et al, "The Kinetics of Rapid High Temperature Stabilization of Cellulose Nitrate", FPL Final Tech Rpt(1957) 239)J.Bonnet, Chim & Ind(Paris) **77**, No 1, 100-2(1957)(Study of nitration of cotton, emphasizing diffusion & swelling phenomena which are main factors in the rate of nitration) 240)G.Molinet, MP **39**, 215-25(1957)(Stability of NC) 241)Y.Lacroix & J.Mars, MP **30**, 227-37 (1957)(Automatic Taliani app for measuring stability of NC) 242)W.A.Schmelling, BOW (Baraboo, Wisconsin), TechRept **165**(1957) (Lab investigation of multiphase nitration of cellulose) 243)P.Lhoste, MP **40**, 77-81(1958) & CA **55**, 3055(1961)(Sulfuric acid impurity in cellulose trinitrate prepd by mixed acids) 244) P.Lhoste & O.Naud, MP **40**, 83-92(1958) & CA **55**, 3053(1961)(Stability of cellulose trinitrate & relation between its ion exchange power and the Abel test) 245)S.Ronssin, MP **40**, 457-71 (1958) & CA **54**, 25825(1960)(Measurement of specific surface of NC's, powders, fibers and of crystals) 246)R.L.Trask, PATR 2494(1958) (Pilot-plant studies of sulfate wood pulp as a source of military NC) 247)E.Kaila, Paperi ja Puu(Helsinki) **40**, 339(1958) & CA **52**, 19121 (1958)(NC dissolved in butylamine or other org amines for use in expls) 248)D.Gross & A.F. Robertson, JRNBS **61**, 413'1958) & CA **53**, 8629 (1959)(Self ignition temps of materials, such as cotton linters & NC plastics) 249)L.Brissaud & P. Miaud, MP **41**, 27-38(1959)(Nitration of wood pulp) 250)Y.Lacroix & N.Bugat, MP **41**, 39-47 (1959)(Detn of NC losses during cooking in an autoclave) 251)C.Fréjacques, FrP 1189916 (1959) & MP **42**, 477-81(1960)(Improvements in nitration of cellulose) 252)L.Brissaud et al, FrP 1200864(1959) & MP **42**, 501-7(1959) (Improvements in nitration of cellulose) 253) M.Giua et al, "Trattato di Chimica Industriale", UTET, Torino **6**(1959), 170-213 254)P. Lhoste & J.P.Dubois, MP **42**, 29-37(1960) & CA **55**, 17005(1961)(Special props of sulfuric ester impurity in NC's) 255)P.Lhoste & O. Naud, MP **42**, 205-22(1960) & CA **55**, 17006 (1960)(Action of NG on NC) 256)M.A.Millett et al, Forest Products Lab Final Rpt", Fundamental Studies on the Characterization of Nitrating Pulps-Stability Studies of Cellulose Nitrate", (1960) 257)ICI, Ltd, Nobel Division, "Industrial Nitrocellulose", Kynoch Press, Birmingham(1961)

**Cellulose Nitrate, Action of Solvents** *(Swelling, Gelatinization, Solubility and Plasticization).* As a general rule solvents for polymers like NC act at first as swelling agents and only afterwards as dispersing reactants. NC is capable of forming "swelling compounds" with a number of org solvents(such as cyclohexanone, fenchone, m-xylene, etc) without losing its fibrous structure. Solubility of polymers like NC is not as clearly defined a property as that of low mol wt compds. When NC is treated with a solvent a "gel" is obtained and the phenomena is known as "gelatinization". If the solvent is volatile, it can be evaporated in order to obtain a plastic-like colloided material. A smokeless NC(or NC-NG) proplnt processed with the aid of an ether-alcohol mixt is an example. If the solvent is non-volatile, or only slightly volatile, the NC forms a gel, but usually heat is required for completion of operation. A double -base(NC-NG) solventless smokeless proplnt is an example. If heating is undesirable(because of danger) gelatinization can be achieved by blending NC at RT, with gelatinizer dissolved or suspended in a liq(such as alcohol) which is not necessarily a solvent for NC. If a solid gelatinizer, such as camphor, is used(as in the prepn of Celluloid), the water-wet NC is mixed with powdered camphor, some alcohol is added and the mass is kneaded at RT for several hours. The process is usually called "plasticization"

It is not very easy to distinguish between "gelatinization" and "plasticization". Both

phenomena give similar plastic-like materials, which are flexible and crack-resistant. Accdg to G.Rugger of PicArsn , a "gelatinizer" tends to draw the molecules together, whereas a "plasticizer" spreads them

The solubility of NC in org solvents and formation of "gels" is attributed to formation of molecular addition compds betw NC and the solvent. Numerous papers were published on this subject and the most important of them are listed below, including their titles or short abstracts

From the practical point of view, it is important to know that soly of NC in a solvent is a function of its N content and to a lesser extent of its viscosity. No categorical statement can be made regarding the soly in any class of solvents. Other factors, such as temp, time, method of manuf, presence of impurities, etc, might also influence the soly but to a lesser extent(See also Refs 32, 34, 64, 69 & 74)
(This section was reviewed by Dr F.J.Masuelli of PicArsn)

*Refs:* 1)M.Marqueyrol & D.Florentin, MP **18**, 150-67(1921) & CA **16**, 2990(1922)(Various gelatinizers for NC) 2)J.Desmaroux, MP **18**, 168-82(1921) & CA **16**, 2990(1922)(Gelatinization of NC and "coefficient of gelatinization) 3)Ab der Halden, MP **18**, 183-4(1921) & CA **16**, 2991 (1922) [Modification of detn of "coefficient of gelatinization" of NC first described by Desmaroux. Procedure: Introduce into a large test tube, provided with a stopper, a sample of NC(0.5g)(previously dried in an oven & cooled) and add 25ml of 2:1-ether-amyl alcohol mixt. Stopper the tube and keep it, with frequent shaking, in a water-thermostat at 20° for 18hrs. After centrifuging, decant 5ml of the clear liquid, evaporate the solvent and weigh the residue. Calculate the coefficient from the formula(Wt of residue)x 100/Wt of sample] 4)J. Desmaroux, MP **23**, 54-62(1928)(Study of gelatinization of NC with camphor) 5)A.J. Phillips, JPhysChem **33**, 118-30(1929)(Behavior of NC in polarized light) 6)J.J.Trillat, CR **191**, 654-6(1930) & CA **25**, 1377(1931) (Gelatinization of NC with camphor; detn of structure of celluloid) 7)J.C.Derksen et al, ZPhysChem **149A**, 371-81(1930) & CA **24**, 5201(1930)(Gelatinization of NC with camphor) 8)J.R.Katz et al, Ibid **151A**, 145, 163 & 172 (1930); CA **25**, 2623(1931)(Gelatinization of NC with camphor; structure of celluloid) 9)A.J. Phillips, PATR **72**(1931)(Study of efficiency of various agents in gelatinization of NC) 10)J.Desmaroux & M.Mathieu, CR **191**, 786-8 (1930) & CA **25**, 2900(1931)(X-ray study of gelatinization of NC with NG, cyclohexanone & acetophenone) 11)J.Desmaroux, MP **24**, 211-33 (1930-1931)(Study of gelatinization of NC with nitroglycol) 12)J.Desmaroux, JChimPhys **1931**, 163-73 & CA **25**, 4170(1931)(Affinity of NC for gelatinizers; a review) 13)A.J.Phillips, PATR **279**(1932)(Study of efficiency of various agents in gelatinization of NC) 14)(?)Thomas, MP **25**, 115-20(1932-1933) & CA **27**, 4083(1933) [Detn of "coefficient of swelling"(coefficient de gonflement" in Fr) in water, ether & eth-alc mixts. This coefficient is defined as "the apparent increase in vol in cc per g of NC as measured after contact for 24hrs betw liquid & NC". For its detn, a sample of dry, pulped NC is placed in a graduated test tube of 12.4mm ID and the height is measured. Then the liq is introduced, the tube stoppered & shaken, allowed to stand for 24hrs and the new height of NC is measured] 15)L.Médard, MP **25**, 449-54 (1932-1933) & CA **28**, 5650(1934)(Relation betw electrical moment and gelatinizing power of NC) 16)P.Demougin, MP **26**, 37-41(1934-5)(Relation betw soly of NC and its N content) 17)M. Mathieu, CR **199**, 55-7(1934) & CA **28**, 5659 (1934)(X-ray examination of gelatinization of N with acetone. It is complete when 1 mol of acet has been fixed by each $NO_3$ group of NC and this is shown by the disappearence of any cryst structure) 18)J.Desmaroux, CR **199**, 148-50(1934) & CA **28**, 5659(1934)[Gelatinization of NC with acetone) 19)M.Mathieu, "La Gélatinisation des Nitrocelluloses", Hermann & Cie, Paris(1936) 20)P.Parodi-Delfino, USP 2096451(1937) & CA **32**, 357(1938)(Gelatinization of NC with NG in the presence of the triacetate of an alkyl, such as of methyl-trimethylol methane) 21)J.T.Power & K.R.Brown, USP 2102187(1937) & CA **32**, 1455(1938)(Gelatinization of NC with NG may be accelerated by a small amt of ethoxyethyl nitrate or acetate) 22)W.A. Sisson, IEC **30**, 530-37(1938)(X-ray diffraction behavior of cellulose derivs) 23)J.T.Power & K.R.Brown, USP 2106188(1938) & CA **32**, 2754 (1938); BritP 498346(1939) & CA **33**, 4788(1939) (Gelatinization of NC with NG is accelerated by the use of ca 1% of an alkyl ether of hexahydric alcohol, contg at least 5 ether groups, such as penta-methyl- or penta-methyl- mannite or sorbite) 24)L.P.Kyrides, USP 2126560(1938) & CA **32**, 7926(1938)(Cyclohexylamine as gelatinizer for

NC) 25)J.Desmaroux, MP **28**, 204-35(1938) & CA **33**, 8469(1939)(Absorption of cyclopentanone by NC) 26)J.D.Hopper, PATR **952**(1939)(Study new solvents as possible ingredients of proplnts) 27)Alvaro-Alberto, AnnAcadBrasilSci **11**, 19-20 (1939) & CA **33**, 5659(1939) [Confirmation of theory of M.Mathieu(See Refs 17 & 19) in case of complete gelatinization of NC with acetone] 28) L.Médard, MP **29**, 10-11(1939) & CA **34**, 1468 (1940)(Study of gelatinization of NC with various mineral acid esters: $Me_3PO_4$ & $Me_2SO_3$ gelatinize all NC's rapidly and completely; $Me_2SO_4$ & 80/20-$EtNO_3$/EtOH gelatinize collodion- and pyrocotton and only incompletely guncotton; $Me_3BO_3$, $PrNO_2$, $BuNO_2$ & $PrNO_3$ have no gelatinizing action on NC) 28a)A.R. Nees, IEC, AnalEd **11**, 142(1939)(Detn of color and turbidity of solns) 29)J.T.Power & K.R. Brown, USP 2146026(1939) & CA **33**, 3590(1939) (Gelatinization of expls, contg NC, with NG is accelerated by the alkyl ester of an anhydric alc contg at least one free OH group and having alkyl group contg not more than 5 carbon atoms, such as methylanhydrosorbitol and dimethyl-anhydrosorbitol) 30)H.Fassnacht, USP 2194544 (1940) & CA **34**, 4908(1940) [Gelatinization of NC with a liq expl ester(such as NG) is accelerated by adding an aliphatic monohydric alc contg a carbonyl group, such as diacetone] 31)T. Petitpas, JChimPhys **37**, 6-18(1940) & CA **34**, 6064(1940)(Study of gelatinization of NC with acetone, cyclopentanone and hydrocarbons) 32) A.Kraus, NC **11**, 226-7(1940)(Action of liquids on NC of various N contents; a table of solubilities of NC's) 33)M.Wadano, Kolloid-Z **92**, 324-38 (1940) & CA **35**, 2634(1941)(Relationship betw N content of NC and its soly) 34)A.Kraus, NC **12**, 63-4(1941)(Soly of NC's of various N content and viscosities in various solvents; a table) 35) É. Calvet et al, CR **212**, 542-4(1941); **213**, 126-8 (1941) & **214**, 716-18(1942); CA **36**, 6073(1941) & **38**, 3888(1944)(Calorimetric study of gelatinization of NC with acetone) 36)N.Ipartelepek, HungP 128457(1942) & CA **42**, 9180(1946)(Gelatinization of NC suspended in hot w) 36a)A.J.Phillips, PATR **1201**(1942)(Study of gelatinizing action of esters of phthalic and adipic acids on NC) 37) A.Soler & A.Vain, Ion(Madrid) **2**, 745-52(1942) & CA **37**, 2572(1943) [Detn of gelatinization of NC with substances usually employed as stabilizers (such as EtCentr, Ph-urethane, etc), expressed as the "coefficient of gelatinization of Soler". This is defined as the max amt in grams that are completely gelled in 2hrs by 1g of the substance] 38)É.Calvet, CR **217**, 482-3(1943) & CA **39**, 2690(1945)(Calorimetric study of gelatinization of NC with acetic esters) 39)A.J.Phillips, PATR's **1249**(1943) & **1587**(1946)(Relation of hydrogen -bonding concept to gelatinization of NC 40)T. Petitpas, MSCE **30**, 201-42(1943) & **41**, 2573 (1947)(Thermodynamic & structural studies of the absorption of various gelatinizers by NC) 41)A.Soler, Ion(Madrid) **4**, 455-63 & 480(1944) & CA **39**, 1055(1945)(Study of gelatinization of NC of 11.8% N with NG in the presence of EtCentr at various stages of the rolling process) 42)A. Soler, AnalesFís y Quím(Madrid) **40**, 266-80(1944) & CA **42**, 8048(1948) [Study of the effect of temp on "coefficient of gelatinization of Soler"(See Ref 37), showed that, generally, it increases with the temp] 43)Kast-Metz(1944), 201-4(Gelatinization ability of NC) 44)É.Calvet, MSCE **32**, 168-99 (1945)(Study of mechanism of gelatinization of NC by employing the microcalorimeter method) 45) É.Calvet & J.Coutelle, MSCE **32**, 200-19(1945) & CA **42**, 8581-2(1948)(Calorimetric study of gelatinization of NC with methyl nitrate acetic esters and ether-alcohol mixts) 46)T.Petitpas & M.Mathieu, TrFaradSoc **42B**, 17-33(1946) (Reactions occuring in the gelatinization of NC's) 47)É.Calvet & G.Sébille, CR **222**, 84-5(1946) & CA **40**, 4284(1946)(Calorimetric study of gelatinization of NC with ether-alcohol mixts) 48)P.F.Macy, PATR **1616**(1946) (Development of explosive plasticizers for NC) 49)B.T.Fedoroff, PATR **1619**(1946)(Development of non-explosive plasticizers for NC) 50)P.F. Macy, PATR **1638**(1947)(Explosive plasticizers for NC) 51)T.Petitpas, Chim & Ind(Paris) **58**, 17-53(1947) & CA **42**, 757(1948)(Review of work done, mostly in France since 1923 on gelatiniza-tion of NC) 52)J.Chédin & R.Vandoni, MSCE **33**, 205-18(1947) & CA **43**, 4927-8(1949) (Discussion on gelatinization of NC with acetone & with other substances) 53)T.Petitpas & M.Mathieu, MSCE **33**, 219-37(1947)(Study of reactions of gelatinization of NC's) 54)B.T. Fedoroff, PATR **1678**(1948)(Prepn of high N, low viscosity NC and the search for efficient non-expl gelatinizers) 55)D.Fenson, CanJRes **26B**, 59-69(1948) & CA **42**, 4347(1948) (Photoelectric study of rate of gelatinization of NC with NG) 56)S.Axelrod, PATR **1681**(1948) (Gelatinization of NC with liq expls, such as nitromethane) 57)B.T.Fedoroff, PATR **1753** (1949)(Non-expl plasticizer for NC) 58)T.C. Castorina, PATR **1755**(1949)(Expl plasticizers for NC) 58a)I.Jullander, Acta Chemica-

Scandinavica **3**, 1309-17(1949)(A simple method for the measurement of turbidity applicable to NC solns) 59)A.T.Blomquist & F.T.Fiedorek, USP 2485855(1949) & CA **44**, 3516(1950) (Nitramines as explosive plasticizers for NC) 60)L.D.Myers & R.W.Webster, USP 2485910 (1949) & CA **44**, 9727(1950)(Plasticizers for NC obtained by oxidation of unsatd fatty acid esters to a degree which renders them compatible with resins and elastometers) 61)W.H.Woodstock, USP 2497920(1950) & CA **44**, 5156(1950)(Alkyl alkenylphosphonates as plasticizers for NC, cellulose acetate and ethyl cellulose) 62)H.M. Spurlin, USP 2510915(1950) & CA **44**, 9728 (1950)(Triesters of 3-ethyldecane-1,2, 10 -tricarboxylic acid as plasticizers for cellulose esters and ethers) 63)H.G.Reid, USP 2517350 (1950) & CA **44**, 11173(1950)(Nonyl esters, especially the benzoate, chlorobenzoate & formate as plasticizers for NC & other cellulose derivs) 64)H.A.Aaronson, PATR **1786**(1950) **(Kinetics of soln of NC's in expl** plasticizers) 65)BritCelanese, Ltd, BritP 654771(1951) & CA **47**, 605(1953)(Monoethers of 1,4-butanediol, such as mono-Bu ether, as plasticizers for NC) 65a)L.Brissaud & M.Leclercq, *MP* **33**, 473-80 (1951)(Electrophotometric detn of turbidity and coloration of NC solns) 66)F.Boyer-Kawenoki & G.Champetier, CR **234**, 1053-5(1952) & CA **47**, 2481(1953)(Fixation of camphor by NC) 67)T. Sakurai et al, JIndExplosivesSoc, Japan **13**, 33-9 & 328-34(1952); CA **49**, 273 & 5844(1955) (Gelatinization of NC with NG) 68)F.Boyer -Kawenoki, CR **236**, 2315-17(1953) & CA **47**, 10840(1953)(Fixation of EtCentr with NC) 69) F.J.Masuelli, "A Study of the Reaction of Cellulose Nitrate with Various Reducing Agents", Doctoral thesis, Virginia Polytechnic Institute, Blacksburg, Virginia(1953), 32-5(Solvation) 70) Ott **5**, Part 1(1953), 333-4(Swelling of NC) 71) T.Sakurai & Y.Sato, JIndExpls Soc, Japan **14**, 111-16(1953) & CA **49**, 11283(1955)(Effect of AN on gelatinization of NC with NG) 72)H.Maisner, USP 2690964(1954) & CA **49**, 618(1955) (Gelatinization of NC with nitroparaffins, such as NMe) 73)G.Desseigne & J.Tranchant, CR **239**, 769-71(1954) & CA **49**, 11285(1955)(Gelatinization of NC with urethanes & substituted ureas) 74) Ott **5**, Pt 2(1954), 714-15(Solvents for NC's); Ibid, Pt 3(1955), 1082-5 & 1451-3 [Soly of NC's of various N contents and viscosities in various solvents; a table based on data of Kraus(Ref 34) and of Hercules Powder Co, Wilmington, Del] 75)T.Okawa,JChemSoc, Japan **76**, 999-1003(1955) & CA **50**, 3036(1956)(Rheological props of NC-NG gels) 76)Anon TM **9-1910** (1955), 218-19(Gelatinization of NC)

**Cellulose Nitrate, Denitration of.** Due to the fact that nitration(esterification) of cellulose is a reversible reaction, proceeding as:

$$(C_6H_7O_2)(OH)_3+xHNO_3 \rightleftharpoons (C_6H_7O_2)(OH)_{3-y}(ONO_2)_y+xH_2O,$$

an equilibrium exists for each concn of nitrating acid, which corresponds to a definite degree of nitration(N content of NC), provided all other conditions, such as temp & pressure remain the same. This means that if the concn of nitrating bath, contg the product nitrated to a certain N content, is slightly weakened by addn of water, the reaction will go from right to left and NC will be partly hydrolyzed to the N content corresponding to the concn of the new nitrating bath. This reaction is known as "denitration"

The denitration practically does not happen if the acid is rapidly diluted with cooling to a very low concn, as, for example, when NC wet with acid is drowned in a large amt of cold w contg ice. If, on the other hand, drowning is done into a small amt of w and the temp is allowed to rise, a certain amt of denitration will take place. It has been observed, that if during wringing out the spent acid, the NC is left in contact with humid atmosphere longer than usual, considerable denitration takes place, especially in outer layers of wrung NC(See also Refs 5,8 & 14)

Although NC is an ester, treatment of it with usual saponification agents, such as aq alkalies, does not yield cellulose and an alkali nitrate but reaction proceeds somewhat differently, resulting finally in decompn (degradation) products of NC, such as modified celluloses and their nitrates, sugars, some organic acids, $CO_2$, etc together with alkali nitrates & nitrates, and ammonia(See also Refs 1,2,4 & 14). It is possible, however, to saponify NC to cellulose without degradation, if treatment is effected by weaker denitration agents, such as by alkaline hydrosulfides, as is used in the manuf of rayon by the "nitrocellulose process" (See also Refs 7,11,14 & 15)

Other methods of denitration are described in Refs 9,10,12,13,14 & 16(See also Ref 13a) (This section was reviewed by Dr F.J.Masuelli of PicArsn)

*Refs:* 1)M.Berthelot, CR **131**, 519(1900)(Study of decompn of NC by alkalies) 2)E.Berl & A.

Fodor, SS **5**, 254, 296 & 313(1910)(Denitration of NC by alkalies) 3)R.C.Farmer et al, JCS **117**, 815-16(1920)(Hydrolysis of Cordite & Guncotton) 4)W.O.Kenyon & H.LeB.Gray, JACS **58**, 1422(1936)(Alkaline decompn of NC) 5) J.Desmaroux, CR **206**, 1483(1938) & CA **32**, 5204(1938)(Denitration of NC by dil acids) 6)M. Mathieu & T.Petitpas, CR **206**, 1485(1938) & CA **32**, 5204(1938)(Denitration of NC and structure & soly of resulting products) 7)F.H.Reichel & A.E.Craver, BritP 512960(1939) & CA **35**, 1228 (1941) USP 2289520(1942) & CA **37**, 532(1943) [Denitration of NC fibers(previously swelled by aq acetone) with a reducing agent, such as alkali hydrosulfide in not more than in 5% soln at 20°] 8)K.Fabel, NC **12**, 143-6(1941) & CA **38**, 2199(1944)(Denitration of NC during centrifuging the product wet with acid may be avoided by excluding air during centrifuging) 9)K.Thinius, GerP 723628(1942) & CA **37**, 5590(1943) (Denitration of NC by suspending the moist product in an inert org liq and treating the slurry with an inorg acid chloride) 10)D.O.Hoffman et al, JACS **69**, 249(1943)(Denitration of NC by $Ac_2O$ & Zn in the presence of either HCl or pyridine) 11)F.H.Reichel & R.T.K.Cornwell, USP 2421391(1947) & CA **41**, 5306(1947) (Denitration of NC with an aq soln of an alk reducing agent, such as NaHS, KHS, $NH_4HS$ or $Ca(HS)_2$ at pH below 12) 12)G.H.Segall & C.B.Purves, CanJChem **30**, 860-71(1952) (Denitration of NC by suspending it in dry pyridine and treating with hydroxylamine, its o-methylethane and their hydrochlorides) 13) M.Soffer et al, JACS **74**, 5301-3(1952) (Denitration of NC by the action of Li-Al hydride) 13a)F.J.Masuelli, "A Study of the Reaction of Cellulose Nitrate with Various Reducing Agents", Doctoral thesis, Virginia Polytechnic Institute, Blacksburg, Va(1953), 31-2 [Denitration is a special case of saponification and is limited to those reactions in which the process is carried out in such a fashion whereby the cellulose is regenerated with the least amt of degradation. The denitrated fibers, however still contain from 1 to 2% N. Denitration with Na hydrosulfide proceeds as follows: $Cell\text{-}(ONO_2)_2+2NaHS \rightarrow Cell+2NaNO_2+2S$] 14)Ott **5**, Pt 2(1954), 720-1(Denitration by spent acid); 730-1 & 753 (by acids); 752-3(by alkalies contg reducing agents); 753(by acid chlorides) & 753(by Li-Al hydride). Ibid, Pt 3(1955), 1096(Denitration by polysulfides) 15)Wolff & Co, GerP 936005 (1955) & CA **52**, 17799(1958)(Continuous denitration of NC by NaHS, followed by desulfurizing) 16)E.P.Swan & L.D.Hayward, CanJChem **34**, 858-62(1956) & CA **51**, 1047 (1957)(Denitration of NC by catalytic hydrogenation)

**Cellulose Nitrate Analytical Procedures.** Various analytical procedures for commerical grade NC's and for some foreign military grade NC's are given in Refs 1-48. The most important source of info for US commerical grades is in Ref 48, where the following tests are described in detail: a)Tests for soluble NC, such as appearence, ash, nitrogen by nitrometer method, stability by 134.5° Heat Test, viscosity by steel ball method, solubility, film test and toluene dilution test by Method **D301**,pp 1061-70 in Pt 6 b)Test and specs for NC (Pyroxylin) plastic sheets, rods & tubes in Method **D701**,pp 227-31 in Pt 9 c)Detn of chain length uniformity by fractional pptn of NC's in Method **D1716**,pp 1105-11 in Pt 6 and 446-52 in Pt 8

British military grade("Service") NC's are described in Ref 33. They are prepd by nitration of either cotton(waste or linters) or wood(in the form of paper or pulp). Nitrogen content of NC's ranges from 10.9-11.4% for "Low Nitrogen, Soluble NC", to ca 13.35 for "Mechanical High Nitrogen NC". The Brit "Pyro", also called "Mechanical Soluble NC", contains 12.45 to 12.75% N

**A)British "Service" Procedures:** a)*Preparation of samples.* NC may be supplied at various stages of its manuf. The samples are taken wet and require preliminary treatment before analysis can begin. The whole wet sample is spread on a large sheet of clean white paper, rubbed well betw the fingers to break all aggregates, mixed thoroughly and transferred to a clean wide necked glass bottle closed by a rubber cap or stopper and labelled "Prepared Wet Sample" (PWS). About 100g of this sample is placed betw several sheets of clean filter paper and transferred to a hand press where it is subjected to heavy pressure for 10 mins. If the paper is well satd with w, the operation is repeated with fresh paper. Then the material is rubbed betw the fingers until free from lumps and transferred to a tray of paper or Al. After lightly covering the tray with a sheet of filter paper(to protect from dust), it is left at RT for 24 hrs. For final drying the tray is transferred to

a thermostatically controlled oven to remain there for 6 hrs at 50°. The dried NC is transferred to a clean, dry bottle, which is closed by a rubber stopper and labelled "Prepared Main Sample"(PMS) b)*Mineral matter(ash).* is detd by burning ca 2g of "PMS", mixed with liq paraffin in a Pt dish over a Bunsen burner, followed by incineration in a muffle furnace at 600°. After cooling, the residue is wetted with 2ml of 5% Amm carbonate soln & heated at 100-105° to const wt c)*Grit* is detd by digesting the "mineral matter" with concd HCl on a water-bath, allowing the insol matter to settle, diluting the liq with an equal amt of distd w & decanting thru a No 41 Whatman filter paper. After washing the dish & filter paper, the filtrate and washings are saved for the detn of "total iron". The filter paper is placed in a Pt dish, dried at 100-105° & then ignited until free from carbonaceous matter. If any grit is present it is transferred with camel hair brush thru a small No 36 BS sieve(see Table, p A674, in Vol 1 of this Encycl) and onto a small No 60 BS sieve. The number of particles retained on each sieve & their nature are reported d)*Total iron* is detd by evapg the combined filtrate & washings from the "grit" test to below 100ml(if the vol exceeds it), transferring the liq to a 100ml vol flask & adding distd w to the mark. After pipetting 25ml into a 50ml std Nessler tube & diluting to the mark with w, add 2ml of 20% citric acid soln, 0.1ml of thioglycollic acid & sufficient amt of 10% Amm hydroxide to produce a sl pink color. After mixing & allowing to stand for 5 mins, the iron content is detd by comparing with color standards in a Lovibond tintometer e)*Alkalinity* is detd by titrating with 0.1N Na carbonate soln, in presence of methyl orange indicator, 100ml of filtered supernatant liq obtd after shaking at intervals for a period of 1 hr & allowing to settle, ca 10g of "PMS" with 100ml 0.1N HCl & 100ml distd w and comparing the reading with that obtained on titrating a blank consisting of HCl & distd w shaken in the same manner. Alkalinity, calcd as $CaCO_3$=(Titre differencexFactor of 0.1N $Na_2CO_3$)/10 f)*Soly of NC of minimum N content 12.75%* is detd by shaking by hand vigorously ca 4g of "PMS" with 150ml of 2:1-ether-alcohol in a 200ml graduate, provided with polythene stopper, followed by mechanical shaking for 6 hrs on a wheel rotating at 15rpm in a water-bath maintained at 15.5°. After allowing to stand until the supernatant liq is quite clear(minimum 4 days), the total vol of content(V) is read and ca 50ml of clear liq is transferred to a tared silica dish, where the solvent is evapd at RT and the residue is heated at 65° to const wt. Then the residue is incinerated with paraffin as described in test(b) and % of organic matter sol in eth-alc is calcd from the formula: [(Wt of residue-Wt of ash)x25V] /Vol of liq evapd(ca 50ml) g)*Soly of NC of 10.9-12.75% N content* is detd by treating ca 0.5g of "PMS" in the same manner as in the test(f), except that 100ml(instead of 50ml) of supernatant liq is removed. Then the vol in the graduate is made up with more eth-alc soln, followed by shaking and allowing to stand overnight. After repeating this opern once more, the total supernatant liq is decanted thru a tared alundum crucible grade RA98 and the residue in the graduate is removed to the crucible by washing with eth-alc. After thorough washing of residue with eth-alc, it is dried(in the crucible) at 65° to const wt and % org matter sol in eth-alc is calcd from the formula: 100-[100x(Wt of residue)] /Wt of NC h)*Organic matter insoluble in acetone* is detd by dissolving ca 1g of "PMS" in 500ml of redistd acet and, after allowing the soln to stand overnight, filtering it thru an alundum crucible grade RA98. After thorough washing of beaker & filtering the washings thru the crucible, it is transferred to a Wiley type apparatus to be extracted for at least 2 days. After drying the crucible in air, it is heated in an oven at 103-105° to const wt. Then the crucible is placed in a small beaker, the residue is wetted with 5% Amm carbonate soln and the ensemble dried at 100° in the open. After removing the crucible from beaker, it is heated at 103-5° to const wt and loss of wt, on ignition, times 100 gives % org matter insol in acet i)*Organic matter soluble in acetone*-alcohol is detd only on NC of low N content(soluble) to be used for purposes other than manuf of solventless proplnts. In this test ca 1g of "PMS" and 150ml of solvent consisting of 93 parts by wt of denatured alc(prepd by mixing 100ps by vol of 92% alc with 4ps of methanol & 2ps of benzene) & 7ps of acetone are shaken(in the same manner as described in test f) in a stoppered tube 43cm long & 2.5cm in diam and then allowed to stand overnight. If the amt of deposit is small, the clear liq is decanted and the residue is shaken with new 150ml portion of solvent. After allowing

to stand overnight, the clear liq is decanted and the residue is transferred quantitatively to the alundum crucible grade RA98, which is then heated in an oven at 75-78° to const wt. If the amt of deposit is appreciable, an aliquot portion of clear liq is transferred to a tared Al dish and, after allowing the bulk of the solvent to evaporate in the open, the final drying to const wt is conducted in an oven at 75-80°. The % matter sol in acet-alc=(Wt of residue x100x150)/(Wt of sample x Vol of aliquot taken) j)*Sulfates* are detd by heating ca 5g of "PMS" with 50ml concd $HNO_3$ in a 400ml beaker until complete dissoln of NC and disappearance of nitrous fumes. The soln is treated with 1g of recrystd $NaClO_3$ in successive small portions and, after evaporating to dryness & allowing to cool, add 20ml concd HCl & 0.5g $NaClO_3$ and the soln is again evapd. After cooling, the residue is removed with a little distd w & the soln filtered(to remove any insol matter) into the 2nd 400ml beaker. Then the 1st beaker is washed and the washings are also filtered. The soln in the 2nd beaker is made up to 200ml with distd w and, after adding 3ml of 10% HCl soln, heated to boiling. To the boiling soln is added slowly 10ml of hot 10% $BaCl_2$ soln and, after continuing to boil for 5mins, the ppt is allowed to digest overnight. The ppt is then transferred quantitatively to a tared Gooch crucible to be dried in an oven at 103-105° for 1 hr, followed by ignition at 800° for 30mins. A blank experiment is carried out at the same time. The % sulfate(calcd as $H_2SO_4$)=(Wt of $BaSO_4$ in detn -Wt of $BaSO_4$ in blank) x 8.404 k)*Settling Test* is conducted by thorough mixing(by means of a round-tipped glass rod) ca 8g of "PMS" with 20ml of distd w in a 250ml beaker. The opern is repeated with three addnl 10ml portions of w and, after addg with stirring another 50ml portion of w, the slurry is transferred quantitatively to a 250ml graduate(with 200ml mark not less than 19cm & not more than 22cm high). After making up to 200ml mark with distd w and stoppering the graduate, it is shaken mechanically for 15mins and then placed for 1 hr on a bench free from vibrations. The vol occupied by settled NC is read and reported as "settling test" l)*Nitrogen content* of NC is detd by Method EA32; *132°C Stability test* by Method EA15; and *170°F Heat Test* by Method EA15. These methods are not available to us at this time

**B)US Military Procedures.** NC for use in proplnts is prepd by nitration of either wood pulp (Spec JAN-C-216) or cotton(Spec JAN-C-206) as is described under Cellulose Nitrate, Manufacture. The finished product shall contain no adulterants, such as alkali, mercuric chloride or other substances which will mask the heat tests in any way. Following are other requirements and tests:
a)*Heat test at 134.5°*. The test is conducted as described in paragraph F-4g(and in Ref 54, Method 404.1) and NC is considered satisfactory if the violet color of std methyl violet paper, 70mm long & 15mm wide, is not completely turned to salmon pink in 25mins, but is completely changed in 30 mins b)*Heat test at 65.5°*. The test is conducted as described in paragraph F-4h and NC is considered satisfactory if the discoloration appearing on the damp portion of std KI-starch paper, 1" long & 0.37" wide(moistened on upper half with 50% glycerine-water) takes place in not less than 35mins c)*Nitrogen content.* The requirements for various Grades and Types are listed under Cellulose Nitrate, Military Grades. The test is conducted by nitrometer method as described in paragraphs F-4a(1)a(1), & F-4a(1)a(2) & F-4a(1)b in Ref 47 & Ref 54, Method 209.3.2 d)*Soly in ether-alcohol.* Requirement for Grade A(ca 12.6%) & for Grade D(ca 12.0%N) is 99% soly, while for Grade B(13.35%) & Grade C(13.25 -13.35%) it is not specified. The test may be conducted by volumetric method [paragraph F-4b(2)] & by gravimetric method [paragraphs F-4b(3)a, F-4b(3)b & F-4b(3)c]. In the *volumetric* test, 1g sample of dry NC is shaken thoroughly in a stoppered Erlenmeyer flask with 75ml of alcohol(US Amy Spec 4-1018 or US Navy Spec 51AB) for ca 5 mins and then allowed to stand for 2 hrs. After adding 150ml of ether(US Spec JAN-E-199), the mixt is thoroughly shaken and allowed to stand overnight without removing the stopper. Then the flask is again shaken and the mixt is transferred to a special solubility tube, 21" long & 1.35" ID, having the lower end constricted for a length of 2" to an ID of 0.3" and graduated in divisions of 0.1ml. After allowing the tube to stand to const vol of insol material(usually several hrs), the reading is taken, and if it is 0.25ml or less, the material is considered 99% soluble and if the vol exceeds 0.25ml, the tube with contents is saved for *gravimetric test.* When Grade A NC is examined, the clear liq in the soly tube of previous opern is siphoned off to the level of ca

0.25" from the upper surface of settled material, without disturbing it. After shaking vigorously, ether is added to within 3" of the top and shaking is repeated. Then the insol matter is allowed to settle and the clear lig is decanted. This opern of washing & decanting is repeated 3 times more. After the 4th decantation, the insol material is washed with 2:1-eth-alc soln into a tared Gooch crucible where it is rinsed thoroughly with eth-alc. Then the crucible is dried in air, heated at 100° to const wt, carefully ignited over a free flame, cooled in a desiccator and weighed. The loss in wt after ignition (A) is considered the wt of insol material and % of soly of NC is equal to: [(Wt of sample-A) x 100] /Wt of sample. When Grades B & C are examined, 100ml of clear soln are drawn from solubility tube of volumetric test (without disturbing the settled material) into an Al can 50mm high & 90ml in diam provided with a tightly fitting cover. The can is then heated slightly on top of closed water-bath and 50ml of distd w is added gradually with stirring & continued heating. After NC has been pptd as finely divided fibres, the heating is continued until the liq evaporates. Then the can is heated at 95-100° to const wt. If the wt of soluble NC in 100ml of clear soln in the can is A, and W is four-ninths of the wt of the original sample, then 100A/W is equal to % of sol NC e)*Acetone insoluble*(max allowed 0.4%). It is detd by wetting ca 1g of dry NC in a 250ml Erlenmeyer flask with 10ml alcohol, followed by shaking with 150ml of filtered 99% pure acetone until complete dissolution. The soln is then passed thru a tared Gooch crucible and the flask is washed with several portions of acet using the washings for rinsing the residue in the crucible. Then the crucible is dried at 100° to const wt and the increase in wt is calcd to % of acet insol f)*Ash*(max allowed 0.4%). It is detd by gelatinizing ca 2g of dry NC in a tared crucible with 5% castor oil soln in acet and igniting the gel. It is allowed to burn without applying heat to the crucible until charred residue remains. Then the crucible is heated to complete the ignition, cooled and weighed. If preferred, NC is digested in the crucible with nitric acid and then ignited by heating the crucible g)*Fineness* (No definite requirement except that NC shall be uniformly pulped & be free from lumps, strings, or material of such consistency as to affect proper colloiding in the mixers). The test is conducted by thoroughly mixing 10g of dry NC in a 250ml beaker with ca 150ml of distd w and transferring the slurry to a 250ml cylinder, 10" long, provided with a stopper and graduated at 2ml intervals. After washing the beaker and transferring the washings to the cylinder(not allowing the vol in the cylinder to rise to more than ca 240ml) the stopper is replaced and the cylinder is thorougly shaken. Then the stopper is removed, the NC adhering to the inner wall of cylinder is rinsed until the vol reaches 250ml, the stopper is replaced, and the cylinder is thoroughly shaken & allowed to stand for 1 hr. The vol occupied by settled NC, after standing, is reported as "fineness" h)*Viscosity*(No definite requirement). The test is conducted by treating 20g of dry NC either in a 16-oz wide mouth bottle or in a liter Kjeldahl flask, with 20g of alc, followed by 160ml of pure absol acet and, after stoppering the bottle(or flask), shaking it in a rotating wheel with the bottle held at 45° to the plane of rotation, until mixing is complete. The mixt is allowed to stand for 24hrs before transferring it to a viscosimeter, which consists of a glass tube 14" long & 1" ID closed at the lower end with a stopper covered with metal foil and having two marks exactly 10" apart(2" from each end of the tube). The tube, filled to 1" from the top, is stoppered and placed for at least 1hr in a water thermostat maintained at 25°. After removing & wiping the tube, it is adjusted in a vertical position(by means of a clamp & stand), the upper stopper removed and several steel balls (having diam 0.793 to 0.795" & weighing 2.025 to 2.045g and previously calibrated with a liq of known viscosity) are dropped in succession. The time required for each ball to pass from one mark to the other is recorded by a stop watch and the average is taken

Requirements and tests for Pyroxylin type NC are described in Specs listed here as Refs 51 & 52 and for Technical NC(for use in organic coatings) in Ref 53. Several US std tests are described in Ref 55. In Ref 49 is described detn of N content of NC by IR spectrophotometry and in Ref 55 detn of NC by chromous chloride reduction. One of the latest methods on detn of N content in NC by ferrous-titanous titration is described in Ref 44. This test will be included in the next edition of US Military Standard Spec

Detn of N content by ferrous sulfate or ferrous ammonium sufate, such as described in Refs 11,12a,37,40 & 43 seems to be rapid and

especially suitable for plant control. However, the use of K nitrate as a "standard" sometimes gives low results and makes this method not as accurate as for example, the nitrometer method. The method developed at PicArsn in 1948(Ref 18) is different because it uses as "standards" NC's of different N contents, previously analyzed by DuPont nitrometer. As this method was never published in the literature, it is, for this reason, described here in detail. The method is essentially as follows: a)Prep "std" ferrous ammonium sulfate-soln(Reagent I) by dissolving, with stirring, 106.15g of pure hexahydrate in ca 900ml of warm soln prepd by mixing 1 part(by vol) of concd $H_2SO_4$(free from $HNO_3$) & 2ps of distd w. Cool the soln, make it up to 1 l and transfer part of it to an automatic 50ml Machlett burette. One ml of this soln is equivalent to 0.0019g of N if titrated against $KNO_3$ or $HNO_3$ b)Prep "std" K nitrate soln(Reagent II) by dissolving 13.72g of pure salt(previously dried for 2 hrs at 100-110°) in 1 l of distd w and transfer part of it to a 5ml automatic semi-micro burette. One ml of this soln is equivalent to 0.0019g of N. This soln is intended for use in "back titration" (See below) c)Prep "std" NC's by accurately detg(by DuPont nitrometer) N contents of pure, dry samples manufd at the plant, such as Guncotton, Pyrocellulose or Pyroxylin and keep the "stds" in jars, tightly closed with rubber stoppers d)StandardizeReagent I by K nitrate. Add slowly(from the burette) Reagent I into a 300ml Erlenmeyer flask, contg ca 0.6g(accurately weighed) $KNO_3$(previously dried for 2hrs at 100-110°), dissolved in 150ml of concd $H_2SO_4$ (free from $HNO_3$). The flask is placed in an ice-bath and is swirled in a rotary manner during titration. The tip of burette is kept inside the flask without touching the surface of liq. The speed of addn is regulated so as to allow the pink coloration, due to the formation of hypothetical complex "$FeSO_4.NO$", to disappear on swirling as soon as it is formed. No accumulation of the reagent on the surface of the liq in the flask is permitted, to prevent possible oxidation of the ferrous ion by air. The titration is continued until the appearance of a permanent pink color. Remove the flask from the ice-bath and "back titrate" the soln with Reagent II until the color turns back to greenish -yel. Take reading and see if one drop of Reagent I turns the soln sl pinkish. If not, take the last reading and add another drop of Reagent I e)Standardize Reagent I by "standard" NC. Transfer 0.6-0.65g of "std" NC into a tared narrow weighing bottle, stopper it and reweigh. Remove the stopper, insert the bottle carefully without upsetting it thru the neck of a 300ml Erlenmeyer flask contg 150ml of concd $H_2SO_4$(free from $HNO_3$) cooled to ca 10°. The flask is provided with a rubber stopper and a glass rod(bent at the lower end to an angle of 45°), fitting loosely in the perforation. Stopper the flask and swirl it in a rotary manner, keeping it in an ice-bath until complete dissolution of NC. Remove the stopper, leaving the glass rod in the flask and titrate with Reagent I, as described under "Standarization of Reagent I by K nitrate". When the pink coloration appears, tip over the weighing bottle by means of the bent rod and if the liq turns greenish-yel, continue titration until pink color is permanent and then "backtitrate" with Reagent II as described in previous test. Take reading f)Detn of N content of unknown sample. Proceed exactly as in previous test using 0.6-0.65g sample dried in the same manner as "std" NC and if reading is closer to that found for "std" Guncotton, use it in calcn; and if reading is closer to that of Pyrocellulose, use this in calcn. If (a) g of "std" Guncotton contg (n)% nitrogen, require(r)ml of Reagent I and if (A)g of test sample require (R)ml of Reagent I, then % N in test sample is calcd from the formula: $n \times \frac{a}{A} \times \frac{R}{r}$

Tests conducted at PicArsn for NC's ranging from 12.46 to 13.95% N gave on the average results within ± 0.02% of nitrometer values

Analytical procedures for acids used for nitration of cellulose will be described under Mixed Acid, Nitric Acid and Sulfuric Acid

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**Celmonite.** A Favier type mining expl which passed the Buxton Test(Brit): AN 67, TNT 12 & NaCl 21%
*Ref:* Marshall **3**(1932), 119

**Celsius, Anders**(1701-1744). Swedish astronomer, known for invention of "centigrade" thermometer, also known as "Celsius" thermometer
*Ref:* EncyclBritannica **5**(1952), 101

**Celtite or Zeltit.** A coal-mine expl invented by Dr R.Nahsen & Co, Hamburg and formerly permitted for use in Brit coal mines, having passed the Woolwich Test. Its compn was: NG 57, NC 8, K nitrate 19, wood meal 9 & Amm oxalate 12 parts
*Ref:* Marshall,Dict(1920), 20 [Compare with Naoúm, NG(1928), 409]

**Cement and Concrete in Ordnance.** The term cement, which includes a great variety of materials, refers here only to the hydraulic material(mainly Portland cement) and the term concrete refers to mixts of cement with sand, gravel, broken stones, etc. and sufficient w to cause the cement to set. If steel rods are used

in combination with concrete, the resulting materials is known as "reinforced" or "armored" concrete(Refs 1,2 & 7)

In addition to using these materials for construction of various bldgs for Ordnance plants or for construction of fortifications(pill boxes, etc ), cement and concrete(except the reinforced) (Refs 8 & 9) were used for manuf of ammo, such as landmines, bombs, mortar shells and hand grenades. This was done in order to save iron, which was a critical material in some countries during WWI & WWII, but it seems that items which were required to produce blast effect rather than fragmentation could conveniently be made of concrete

Some of the cement or concrete ammo items used during WWII by the Czechs, Germans, Italians and Japanese are listed in Refs 3,4,5 & 6

*Refs:* 1)Kirk & Othmer **3**(1949), 411-499 2) EncyclBritannica **5**(1952), 104-11 & **6**(1952), 207-12 3)Anon, "German Explosive Ordnance", TM 9-**1985-2**(1953), 39-43(Concrete Bombs, 12kg, 50kg & 250kg); 60-5(Concrete Practice Bombs, 10kg, 50kg, & 250kg); 83(BLC 50 Photoflash Bomb with cement ballast); 277-78 (Concrete A/P Stockmine and Concrete A/P Ball Mine) 4)Anon, "Japanese Explosive Ordnance", TM **9-1985-4**(1953), 26[15kg Bomb, Concrete (with steel pellets set in)]; 27-8(10kg & 30kg Concrete Substitute Bombs); 29(4kg Practice Bomb with concrete nose); 228[1-lb Hand Grenade with body made of pottery clay, glazed or unglazed)(There is no reason why pottery body cannot be substituted by concrete body) 5)Anon, "Italian and French Explosive Ordnance", TM **9-1985-6**(1953), 2(Ital 3kg A/P Bomb with part of the body made of concrete with steel fragments embedded in it); 21(Ital 5kg Vento-Marker with part of the body made of concrete), 23(Ital 3kg AA Bomb with concrete body contg steel pellets embedded in it) 6)H.H. Bullock, Museum, PicArsn [Czech 210 Mortar Shell(Outer body made of steel 1/8" thick, the inner casing 1/32" thick and betw them concrete body, 1 9/16" thick with steel fragments embedded in it) 7) R.F.Blanks & H.L.Kennedy, "Technology of Concrete and Cement, Vol 1, Wiley(1955) 8)ASTM Standards(1961), Part 4 (Specs for various cements and concrete) 9)US Military and Federal Specifications for cements used by Armed Forces are listed in "Index of Specifications and Standards", US Dept of Defense, Washington 25, DC, Part 1 with Cumulative Supplement dated 30 July, 1961

**Cement, Acid-Resistant.** See under Acid-Resistant Materials in Vol 1,pp A92-A93 of this Encyclopedia

**Cement for Laboratory Use.** A Cement similar to DeKhotinsky commercial product may be prepd by heating, with frequent stirring, at not over 140°, 3 lbs shellac scales with 1 pint of North Carolina pine-tar oil, followed by pouring the resulting uniform mixt into molds of the desired shape

*Ref:* InorgSynth **1**(1939), 189

**Cement, Pettman.** A mixt of iron oxide, shellac, alcohol, rosin, ethyl cellulose & pine tar, used to seal fuzes etc. in projectiles

*Ref:* 1)Glossary of Ord(1959), 63 2)US Joint Army-Navy Specification JAN-C-99(1)

**Cement, Pyroxylin.** A mixt contg pyroxylin (collodion cotton), a solvent and a plasticizer; used for cementing NC plastics to other materials

*Ref:* CondChemDict(1961), 238

**Center-Fire Cartridge.** See under CARTRIDGE, AMMUNITION, Small-Arms Cartridges

## CENTRALITES

*Introduction.* The term "Centralite"(Zentralit or Centralit in Ger; Centralite in Fr & in Ital; Centralita in Span and Tsentralit in Rus) is derived from the name of the "Central Laboratory for Scientific & Technical Research at Neubabelsberg, Germany(Zentralstelle für wissenschaftlich -technische Untersuchungen zu Neubabelsberg), where these compds were first investigated, beginning ca 1906(Ref 8). The term "Centralite" usually designates some N,N'-dialkyl derivs of carbanilide(sym-diphenylurea),which were found to be suitable for use as solid non-volatile, gelatinizer-stabilizers in smokeless proplnts. These substances, the most important of them Centralite 1(Ethyl Centralite) or N,N'-diethyl-carbanilide, also possess the property of reducing the temp of burning of proplnts, thus acting as a flash-reducer. Being neutral, Centralites can be used in proplnts contg NG

For incorporation in smokeless proplnts, Centralites are usually dissolved in a volatile solvent(such as alcohol) and the soln is added to the mixer contg the proplnt slurry. If the proplnt is going to be "solvent type"(such as Cordite or Ballistite), the slurry consists of NC, NG & a volatile solvent(such as acetone) and if it is to be

"solventless type"(such as rocket proplnts), the slurry contains NC, NG & water

The term "Centralite" was recently extended to include one of the alkylaryl -carbanilides prepd in France(see Centralite 4). There is also Butylcentralite to which no numerical designation has been given(See Centralite, Butyl)

**Centralite 1 or Ethylcentralite**(US); **Carbamite** (Brit); *Centralit I* or *Zentralit I*(Ger); *Mollit I* (Ger trade name for product used as a plasticizer); *N,N'-Diethylcarbanilide* or *N,N'-Diethyl-N,N'-diphenylurea*, $OC[N(C_2H_5)\text{-}C_6H_5]_2$; mw 268.35, N 10.44%; col crysts (from alc); mp 72.4°(79° is given in Refs 1, 2, 19, 22 & 30); sublimes above its mp, but not as easily as does camphor, bp 325-30°; volatile with steam(Ref 19); d 1.14 at 25°(detd at PicArsn); d 1.12 at 20°(Ref 39); $Q_c^v$ 8409.3 cal/g(Refs 15 & 24); $Q_f^v$ 97.5 cal/g(Ref 24) & 94.4 cal/g or 25.3 kcal/mole(Ref 32a); $Q_f^p$ 31.9 kcal/mole(Ref 32a); calorific constant(h) -24.4 cal per 0.01g of Centr 1 which corresponds to calcd calorific value at const pressure 2253 kcal/mole at 17°, vs experimental value 2264.6kcal/mole(Ref 25). Its soly in various org solvents was detd by Desvergnes(Ref 6) and at PicArsn. Soly of Centr 1 in 100g of water: 3mg at 0°, 8mg at 20°, 12mg at 50° and 30mg at 85°; soly in 100g of absol alcohol: 72.67g at 20° and 515.2g at 50°; 0.584g of Centr 1 dissolves in 1g of acetone at RT and 0.877g dissolves in 1g of solvent consisting of 63% acetone & 37% alcohol. Centr is also sol in glycerin and in NG

Centr 1 was first prepd in 1876 by Michler et al,(Refs 1 & 2) by heating ethylphenyl-carbamyl chloride with monoethylaniline at 130° or by heating diethylaniline with phosgene, under pressure. Vaganay & Wevert patented the method(Ref 34), which, when reduced to a laboratory scale, is as follows:

In a 1 liter round-bottom flask(provided with a stirrer and placed in an ice-water cooling bath), contg 450g of 7% aq NaCl soln & 363.5g of monoethylaniline, $C_6H_5.NH(C_6H_5)$, cooled to 0-4°, is introduced slowly(for ca 3hrs), below the surface of liquid, 163g phosgene, while stirring and maintaining the temp below 4°. The resulting slurry, contg in suspension ethyl-phenylcarbamyl chloride, and in soln ethylaniline chloride, is stirred for addnl 30mins and transferred to a flask of 1.5-l capacity contg 412g of 33% aq NaOH soln. The mixt is heated for 3hrs at 80° and transferred to a large separatory funnel. After discarding the lower(aqueous) layer, the upper(organic) layer is washed twice with 400g portions of 4.5% aq HCl at temp of 80°(to eleminate any alkalinity), followed by four washings with w at 80°(to eliminate chlorine ions). The crude product is melted in a flat dish and kept at ca 80° in a vacuum oven until the product is dry. This treatment also removes nearly completely, any monoethylaniline which may remain as impurity after washings. This method is claimed to give a product with a mp ca 72.3° and a yield of 89%, based on monoethyl-aniline used. The impurities in Centr 1 should not be more than 0.005% of chlorine and 0.04% of secondary amine

Mechanism of stabilization of proplnts by Centr 1 and its gelatinizing and stabilizing powers are discussed in Refs 3,5,9,12,13,14,18, 20,21,23,26,27,28,30,31 & 33. Formation of complexes of Centr 1 with various substances are given in Refs 7,10,32,35 & 38. Recovery of Centr 1 and of other compds from double-base proplnts is described in Ref 36. Synthesis of various compds which are formed from Centr 1 during the aging of double-base proplnts is described in Ref 29. Binary mixts and molecular combinations of Centr 1 with various compds are discussed in Refs 7,10,11 & 35. Addnl information on Centr 1 may be found in Refs 4,8,16,17,19 & 24

*Uses:* After WWI it was manufd in Ger under the name of Mollit 1 for use as a plasticizer (Ref 1, p[238] & Ref 4). Its use as gelatinizer-stabilizer-flash reducer in smokeless proplnts was already mentioned under CENTRALITES, Introduction. It has also been used as an age-retarder in vulcanized rubber (Ref 39)

When used in proplnts in small quantities (ca 1%) Centr 1 acts only as a stabilizer, while larger quantities(3-10%) are used when it is required to act also as a gelatinizer for NC and, sometimes, as a flash-reducer(Ref 37)

Following are examples of proplnts contg Centr 1: a)Ger, single-base: NC(13.1% N) 93.5, Centr 2.8, Acardite 0.6, graphite 1.5, K sulfate 1.1 & unaccounted 0.5%(Ref 37) b)Ger PETN proplnt: NC(13.2% N) 56.0, PETN 34.0 & Centr + DNT 10%(Ref 37) c)Ger double-base: NC(12.5% N) 58.1, NG37.2, Centr 3.9, K sulfate 0.3 & unaccounted 0.5%(Ref 37) d)Ger, double -base: NC(12.9% N) 59.6, NG 39.0, Centr 0.7, graphite 0.1 & unaccounted 0.6% e)Ger,

double-base: NC(12.3% N) 64.0, NG 30.0 & Centr 6.0%(Ref 37) f)Ger, double-base: NC(12.2% N) 63.0, NG 28.0 & Centr 9.0%(Ref 37) g)Ger, double-base: NC(12.1% N) 65.1, DEGDN 31.5, Centr 2.7, graphite 0.3 & K sulfate 0.4%(Ref 37) h) Ger, double-base: NC(11.9% N) 65.0, DEGDN 23.2, Centr 8.8, graphite 0.1, K sulfate 1.5 & unaccounted 1.4%(Ref 37) i)Ger proplnt S6702: NC(12.0% N) 29.5, DEGDN 29.5, AN 40.0 & Centr 1.0%(moisture ca 1.1% is not considered)(Ref 37) j)Brit Cordite N: NC(13.1% N) 19.0, NG 18.5, NGu 54.7, Centr 7.5, & cryolite ($K_3AlF_6$) 0.3% with chalk 0.15% added(Ref 24a,p 107) k)Amer, H-4 rocket proplnt: NC 58.0, NG 30.0, DNT 2.5, Centr 8.0 & K sulfate 1.5%(Ref 24a,p 153) l)Amer, JPT rocket proplnt: NC(13.25% N) 59.0, NG 40.0 & Centr 1.0% and added DPhA 0.2 & nigrosine dye 0.1%(Ref 24a,p 153) m)Amer, M5 cannon proplnt: NC(13.25% N) 81.95, NG 15.0, Ba nitrate 1.4, K nitrate 0.75, Centr 0.6, graphite 0.3, residual alcohol 2.3 & residual water 0.3 parts(US Spec JAN-P-323) n)Amer, M15 cannon proplnt: NC(13.15% N) 20.0, NG 19.0, NGu 54.7, Centr 6.0, cryolite 0.3 & residual alc 0.3%(US Spec MIL-P-668A) o)Amer, M17 cannon proplnt: NC(13.15% N ) 22.0, NG 21.5, NGu 54.7, Centr 1.5, cryolite 0.3 & residual alc 0.3%, with graphite 0.1% added(US Spec MIL-P-668A) p)Amer, M7, mortar & small arms proplnt: NC(13.15% N) 54.6, NG 35.5, K perchlorate 7.8, Centr 0.9, carbon black 1.2 & residual alc 0.8%(US Spec JAN-P-659) q)Amer, M9, mortar & small arms proplnts: NC (13.25% N) 57.75, NG 40.0, K nitrate 1.5, Centr 0.75 & residual alc 0.5%(US Spec MIL-P-20306) r)US, T18, recoilless rifle proplnt: NC(13.15% N) 72.0 NG 19.75, Ba nitrate 0.75, K nitrate 0.7, Centr 6.5, graphite 0.3, residual alc 1.2 & residual water 0.3 parts(Pic Arsn Spec PA-PD -329) s)US, T28 recoilless rifle proplnt: NC (13.15% N), 67.25, NG 25.0, Ba nitrate 0.75, K nitrate 0.7 Centr 6.0, graphite 0.3, residual alc 1.2 & residual water 0.3%(US Spec OAC-PD-134)(See also Centralite 1, Analytical Procedures; Centralite 1, Nitro Derivatives of; and Centralite 1, Transformation Products, Formed During Aging of Propellants Containing It)

*Refs:* 1)Beil **12**, 422 & [238] 2)W.Michler et al, Ber **9**, 712 & 1913(1876) 3) T.L.Davis, IEC **14**, 1141(1922)(Gelatinizing power of Centr 1 for straight NC proplnts is higher than that of Centr 2, but lower than Butylcentralite. It seems that the heavier the alkyl group in substituted diphenylureas, the greater is the gelatinizing power) 4)Naoúm, Expls(1927), 103(Centralites 1,2 & 3 were manufd in Germany after WWI, by the firm Weiter-ter-Meer in Uerdingen am Rhein under the names Mollit 1, Mollit 2 & Mollit 3) 5)H.Lécorché & P.Jovinet, CR **187**, 1147-8(1928) & CA **23**, 3345(1929)(Mechanism of stabilization of double-base proplnts by Centr 1 & DPhA. It was concluded that Centr 1 is a better stabilizer than DPhA when in presence of NG) 6)L. Desvergnes, AnnChimAnalChimAppl **10**, 226-8 (1928) & CA **22**, 4034(1928)(Soly of Centr 1 in org solvents) 7)L.Médard, MP **24**, 174-210 (1930-31)(Study of molecular combinations of Centr 1 with various compds) 8)Stettbacher (1933), 197(Centralites 1 & 2 were first investigated in Germany ca 1906 as possible stabilizers for NC in smokeless proplnts) 9)M. Giua & M.Guastalla, Chim & Ind(Paris **29**, 272-7(1933) (Action of stabilizers, including Centr 1, on NC, MNT, DNT, TNT, PA & some other expls) 10) L.Médard, Chim & Ind(Paris) **30**, 277-80(1933) (Discussion on possibility of existence of complex DPhA-EtCentr) 11)T.Urbański, Rocz-Chem **13**, 399(1933) & **15**, 191(1935); CA **28**, 27(1934) & **30**, 2834(1936)(Binary mixts of EtCentr with HNMnt, eutectic point 52.1°; with PETN 68° and with Erythritol Nitrate 42.2°) 12)M.Tonegutti, SS **32**, 300-5(1937) & CA **32**, 1099(1939)(Stabilizing power of Centr 1 detd by methods of Taliani or Thomas compares closely with those for DPhA and Acardite) 13)T. Urbański & W.Miladowski, SS **33**, 247(1938) & CA **33**, 385(1939)(DPhA was shown to be a better stabilizer for NC than Centr 1) 14)R.Dalbert, MP **28**, 147-55(1938) & CA **33**, 7569(1939) (Comparison of double-base proplnts stabilized with Centr 1, DPhA or carbazole showed that denitration of NG & NC and lowering of viscosity of proplnt were least with Centr 1) 15)E.Burlot, MP **29**, 251(1931)(Some props of Centr 1) 16) Thorpe **4**(1940), 521(Some props of Centr 1) 17)Davis(1943), 319(Centr 1 has superseded Centr 2 for use in smokeless proplnts) 18)Alvaro Alberto, AnaisAcadBrasilCienc **16**, 311-2(1944) & CA **39**, 3160-1(1945)(Stabilizing power of Centr 1 in double-base proplnts) 19)Kast-Metz (1944), 165 [Some props of Centr 1] 20)L. Pauling, OSRD Rept **4821**(1945) [Thermal stability of trench mortar sheet proplnts such as those contg(approx): NC(ca 13.22% N) 52.2, NG 43.0, DEtPh 3.0, EtCentr 0.6 & K sulfate 1.2%, were better than of similar proplnts contg DPhA] 21)L.Pauling, OSRD Rept **5418**(1945) (Thermal stability of Ballistite type proplnts contg EtCentr did not seem to be better than of

those contg, DPhA. Incorporation of DEtPh in Centr contg proplnts improved their stability) 22)Pérez Ara(1945), 423(Some props of Centr 1) 23)All & EnExpls(1946), 42(Centr 1 acts in proplnts as gelatinizer for NC and as stabilizer & flash-reducer) 24)H.Muraour & G.Aunis, MAF **20**, 433(1946)(Some props of Centr 1) 24a) "Summary Technical Report of Division 8, NDRC," Vol 1(1946), 107 25)J.Taylor et al, JPhysCollChem **51**, 590-1(1947)(Calorific constant and calorific value for Centr 1) 26)P.F. Macy, PATR **1641**(1947)[Investigation of stabilizers for double-base proplnt(rocket, trench mortar & artillery), showed that carbazole, asym-DPhUrea and Centr 1 are better stabilizers than DPhA) 27)R.Dalbert & H.Ficheroulle, MP **30**, 283-300(1948)(Investigation of various org compds from the point of view of their utilization as stabilizers-gelatinizers in smokeless proplnts to replace Centr 1 or DPhA showed that the following compds might prove of interest: 2-acetylphenanthrene, butyloxalate, carboxybutylmorpholine, carboxyethylmorpholine and ethylene-1,2-diurethane) 28)A.G.García-Gutiérrez, Ion(Madrid) **9**, 165-71(1949) & CA **43**, 6825(1949)(Review of substances, including Centr 1, used as stabilizers in smokeless proplnts) 29)P.E.Wilcox & W.A.Schroeder, JOC **15**, 944-9(1950)(Synthesis of various compds formed from Centr 1 during the aging of double-base proplnts) 30)W.R.Grassie et al, CanJRes **28B**, 468-84(1950) & CA **45**, 3594(1951)(Stabilizing props of Centr 1 in comparison with possible new stabilizers for NC) 30a)W.A.Schroeder et al, AnalChem **23**, 1743(1951)(UV & visible absorption spectra) 31)Stettbacher, Polvoras(1952), (Gelatinizing power of Centr 1 is reported to be lower than that of Acardite or DPhA, but higher than DPhUrethane) 32)F.Boyer-Kawenoki, CR **236**, 2315-17(1953) & CA **47**, 10840(1953)(Fixation of Centr 1 in cyclohexane by NC of 12% N) 32a) L.Médard, MAF **28**, 480(1954)(Some thermochemical data) 33)G.Desseigne & J.Tranchant, CR **239**, 769-71(1954) & CA **49**, 11285(1955)(Influence of certain groups in substituted ureas, such as Centralites, on their gelatinizing power for NC) 34)J.Vaganay & S.Wevert, FrP 1058486(1954) & MP **37**, 525-8(1955)(Improvement in prepn of Centr 1 and of other symmetrical dialkyldiarylureas) 35)M.Parpaillon, MP **38**, 233-41(1956) & CA **51**, 11717(1957){Formation of complex EtCentr-NGu, $OC[N(C_2H_5).C_6H_5]_2$-HN:C$\langle^{NH_2}_{NH.NO_2}$} 36)R.R.Buell, USP 2843584(1958) & CA **52**, 21112(1958)(Recovery of Centr 1 and other compds from double-base proplnts) 37)B.T.Fedoroff et al, PATR **2510**(1958) pp Ger 27 & Ger 141-5 37a) M.Giua et al, "Trattato di Chimica Industriale", UTET, Torino **6**, (1959), 363-4 38)G.Chérubin, JChimPhys **57**, 361-73(1960) & CA **54**, 21938 (1960)(Intermolecular linkage betw Centr 1 & NC) 39)CondChemDict(1961), 375(Props & uses of Centr 1)

**Centralite 1 Analytical Procedures.** Centr 1 can be detected by various colorimetric tests, such as described in Refs 1,6,12,24,28 & 33. Some other qualitative tests are given in Ref 13. Quantitative detns of Centr 1 by bromination methods are described in Refs 4,5,7,9,10,14,16,17,20,27,34 & 35. Chromatographic and spectrophotometric methods are found in Refs 11,15,18,21,22,23,24, 29,30,32 & 33. Other quantitative methods, including polarographic, are in Refs 2,7a,20a,25, 26,27 & 30. X-ray diffraction spectra data are given in Ref 19. Detns of stabilizing action of Centr 1 by methods of Taliani and Thomas are discussed in Refs 3 & 8

The following qualitative tests for EtCentr has been used at PicArsn:

a)*Potassium Dichromate Color Test.* To ca 1mg sample placed on a spot plate, are added, while stirring, 3 drops of concd $H_2SO_4$ and ca 1mg of $K_2Cr_2O_7$. A raspberry-red color indicates the presence of Centr

b)*Concd Sulfuric-Dilute Nitric Acid Color Test.* To ca 1mg sample placed on a spot plate are added while stirring 3 drops concd $H_2SO_4$ and 1 drop dil $HNO_3$(6 drops concd $HNO_3$ to 100ml distd water). A raspberry-red color indicates the presence of Centr

c)*Precipitation as Dibromocentralite Test.* To ca 100mg sample dissolved in 5ml glacial AcOH are added 20 drops of liq Br and the mixt allowed to stand for ca 30mins. After removing AcOH and the excess Br by bubbling with air, the residue is dissolved by heating in 20ml ethanol and, while the soln is boiling, cold water is added in small portions until a small amt of permanent residue is formed. After cooling the mixt, some of the wh crysts are collected, dried and tested in Fischer (or equivalent) melting point apparatus (mp of dibromocentralite is 123.0-123.5°)

Centralite 1, intended for use in US military proplnts(Ref 36) shall be supplied in the form of either white lumps(Class 1), powder (Class 2) or flakes(Class 3), consisting essentially

of diethyldiphenylurea. All classes shall be free from grit or visible impurities and meet the following other requirements:

I)*Solidification Point* -71° to 72.5° incl and the substance shall melt to a bright clear liquid, free from scum and deposit. Test shall be conducted in an apparatus similar to the one described in Ref 36,p 313-R, except that the 2nd thermometer is provided for correction. The inner tube, filled to within 1½" of the top with molten Cent, is inserted in the larger tube, which in turn is placed in a large mouth bottle, 100ml capacity, filled to within 1" of the top with water at 65°. The 1st thermometer(standard) is adjusted so that the bulb is in the center of molten material, while the bulb of the 2nd therm is in the air space above it and in the mid point of the exposed Hg column of the 1st thermometer. The molten material is stirred vigorously by up and down movemtnts of hand stirrer until solidification begins and the temp stops falling. Then the temp will start to rise and is observed carefully until the maximum is reached. This temp is recorded as the uncorrected solidification point(T). This max temp is corrected for emergent stem by adding the value calcd from the formula: N(T-t) x 0.000159, where N=degrees in the exposed mercury column, T uncorrected solidification point, t=av temp of the exposed Hg column detd by means of the 2nd thermometer and 0.000159= coefficient of expansion of Hg in glass

II)*Volatile Matter* - 0.1%, maximum. It is detd by heating a 5g sample in a tared shallow dish, for 2hrs at 60°, cooling in a desicator and weighing

III)*Ash Content* - 0.3% max. It is detd by placing a 5g sample in a tared crucible, adding alcohol to completely cover the sample and igniting the mixt. After completion of combustion, the crucible is heated to redness until all carbon has been removed, cooled in a desiccator and weighed

IV)*Secondary and Tertiary Amines.* The sum, calcd as ethylaniline and diethylaniline, respectively, shall not exceed 0.20%

a)Secondary amines. A 25g sample, dissolved in 30ml of benz contained in an Erlen fl is treated with 5ml of N/4 soln of $Ac_2O$ in xylene and, after stoppering the flask, allowed to stand overnight, Then 25ml of N/10 NaOH soln is added and, after thorough shaking, the mixt is transferred to a separatory funnel and to this are added distd w washings of the flask. After adding 25ml of N/10 HCl, the funnel is shaken and allowed to stand. The separated aqueous layer is transferred to a beaker and, after adding distd w washings of funnel, the mixt is titrated with N/10 NaOH soln in presence of phpht indicator. A blank detn, using the same ingredients as above except Cent, is run simultaneously

%Ethylaniline = $[12.1(V_1 - V_2)N]/W$, where $V_1$ = ml of NaOH soln required for blank; $V_2$ = ml of NaOH soln required for sample; N=normality of NaOH soln and W=wt of sample

b)Tertiary amines. A 5g sample in 20ml of benz contained in a separatory funnel is thoroughly shaken with 20ml of N/2 HCl and then allowed to stand for few mins. The separated aq layer is transferred to a 50ml Nessler tube to which are also added distd w washings of funnel and 2 ml of N $NaNO_2$ soln. Then the contents of tube are made up to 50ml mark and, after thorough shaking, allowed to stand for 30min. By means of a colorimeter the color is compared with standards contg known amts of diethylaniline

V)*Acidity* - shall not exceed 1ml of N/10 NaOH soln per 100g of Centr. A 10g sample is melted in 30ml of hot distd w contained in a flask and the mixt is shaken vigorously until Centr crystallizes. After cooling the mixt to RT, it is titrated with N/10 NaOH in presence of phpht indicator. At the same time the vol of N/10 NaOH required for a blank is detd and this is deducted from vol required for the sample. The corrected reading shall not exceed 0.1ml of N/10 NaOH for 10g sample

VI)*Hydrolyzable Chlorine Compounds* - shall be absent. A 5g sample contained in a beaker is warmed on a water-bath for 15mins with 10ml of 5% Na ethylate soln in alc, then diluted with cold distd w, allowing Centr 1 to crystallize. The slurry is filtered, the filtrate acidified with concd $HNO_3$ and tested for chlorine ion by adding 5ml of 10% $AgNO_3$ soln. The opalescence shall not be greater than that produced by a reagent blank

VII)*Particle Size.* Class 2(powder) - a minimum 99.9% of the material shall pass thru a US Std No 30 sieve; Class 3(flakes) - a min 99.9% shall pass thru No 3½ sieve; the average of the max thickness of 25 flakes, as detd by micrometer, shall not exceed 0.025". The screen test is conducted by placing a 100g sample on the required screen provided with a bottom pan and a cover and shaking either by hand(for 10mins) or for 5 mins by means of a mechanical shaker geared to produce 300±15 gyrations and 150± 10 taps of the striker per min(Comparison of US Std Sieves with Tyler, Brit & Ger series is given in Ref 35, Table 1,p A674)

**Determination of Centralite 1 in Propellants**

*A. Volumetric Bromination Method*(For detn of Centr 1 in newly manufd single- or double-base proplnts contg no other brominatable materials, such as DPhA, acardites, urethanes, p-nitromethylaniline and salicylates). This method, described in Ref 34 as Method 202.2.2, consists of the following operations:

a)*Preparation of Sample.* If the proplnt consists of grains weighing 0.2g or less, it is carefully ground, few grains at a time to pass a 10-mesh screen. A laboratory mill, such as Wiley, Model No 2G(provided with a shield and an explosion -proof motor) is used for this purpose(See Ref 34, Method 509.3.1). The ground sample is placed immediately in a bottle with ground-glass stopper. For larger than 0.2g grains, they are sliced by means of "powder cutter" with beryllium alloy blade, to pieces ca 0.17mm thin and these are cut into pieces ca 1/8" square prior to grinding them in the laboratory mill, as above. In case of sheet proplnt; it is cut into pieces ca 1/8" square using beryllium alloy shears, and the cut pieces are placed immediately in a bottle provided with a glass stopper. Before grinding the pieces in the mill, they are made brittle by chilling them. For this, the bottle is placed in an ice-salt bath until the grains become brittle(Ref 34, Method 509.3.1)

b)*Extraction of Sample.* A 5g sample(weighed to within 0.2mg), of ground proplnt is transferred to an extraction thimble which is placed in an extractor(such as Soxhlet or Wiley), provided with a condenser(such as Allihn type) and an extraction flask. After filling the flask to about half with anhydrous methylene chloride, $CH_2:Cl_2$(US Military Spec MIL-D-6998)(See Note below), the apparatus is assembled and the flask is heated on a hot plate, adjusting the temp so that the solvent drips from the condenser to the thimble at the rate of 2-3 drops per second. The operation is continued until the extraction is completed. This can be verified by testing colorimetrically(see at the beginning of this analytical section) the liquid dripping from the thimble. When the extraction is complete, the solvent is evap, using a stream of dry air and the dry residue is retained for further tests(Ref 34, Method 104.1.3)

*Note:* Methylene chloride is used as extraction solvent (in preference to ether or $CCl_4$) because it has a low solvent effect on NC and is safe to handle

c)*Determination of Centralite 1 in Extracted Material.* The dry residue in extraction flask is dissolved in 10ml of glacial AcOH(US Spec JAN-A-465) and, if the nominal content of Centr in the proplnt is less than 4%, the soln is transferred to a 250ml iodine titration flask. Then the extraction flask is rinsed with four 10ml portions of glac AcOH transferring the rinsings to the iodine flask. After cooling the soln to $20^\circ \pm 2^\circ$, exactly 25ml of N/5 std bromate-bromide soln is added

*Note:* This soln is prepd by dissolving in distd w 5.6g of $KBrO_3$ dried at $100^\circ$ & 30g of KBr and diluting the soln to 1 liter with distd w(see Method 605.1 of Ref 34). It is standardized with N/10 Na thiosulfate soln which is prepd by dissolving 26g of pure $Na_2S_2O_3 \cdot 5H_2O$ & 0.1g of $Na_2CO_3$ in sufficient amt of distd w to make 1 liter and standardizing it, after allowing to stand for at least 24hrs, with $K_2Cr_2O_7$ soln in presence of KI & HCl as described in Method 602.1 of Ref 34

Then the stopper of the flask is moistened with one drop of 15% KI soln, 5ml of 38% HCl soln is added to the flask and exact time is noted. The flask is stoppered immediately and swirled for few seconds to allow the bromination to proceed. After elapse of $1.0 \pm 0.25$ mins from the time of addn of HCl, the stopper is removed, 10ml of 15% KI soln is added and the flask swirled. Then the gutter and walls of the flask are rinsed with distd w and the contents is titrated immediately with 0.1 N std Na thiosulfate soln until the appearance of light yellow color. Finally, 5 ml of starch indicator soln is added and titration continued until the blue color of soln disappears

*Note:* Starch indicator soln is prepd by dissolving 2g of soluble starch and 1-2 milligrams of $HgI_2$(as preservative) in a small amt of cold distd w, pouring the soln slowly, with stirring, into 500ml of boiling, freshly distd w and continuing to boil for 5mins(See Method 701.1 in Ref 34)

A blank is run simultaneously with sample, using 50ml of glac AcOH & 25ml of 0.2N bromate -bromide soln. The percent of Centr 1 is calcd from the following formula: $[6.71(A-B)N]/W$, or in case of Centr 2(Methylcentralite): $[6.01(A-B)N]/W$, where A=ml of Na thiosulfate soln required for the blank; B = ml of thiosulfate soln required to titrate liberated iodine in the soln contg the brominated sample; N=normality of thiosulfate soln and W=weight of sample corrected for total volatiles

*Note:* If the Centr 1 content of the proplnt is expected to be betw 4 & 6%, the contents of extraction flask is dissolved in 10ml of glac AcOH [See opn (c)] and transferred to a 100ml volumetric flask. After rinsing the extraction

flask with four 10ml portions of glac AcOH and transferring the rinsings to a vol flask, its content is made up to 100ml mark with glac AcOH. Then 50 ml is pipetted into iodine flask and used for bromination as described in opn c. If more than 6% of Centr 1 is expected to be in the proplnt, only 25ml of soln in volumetric flask is transferred to iodine flask and to this is added 25ml of glac AcOH before the bromination procedure

*B. Bromination Method* [For detn of available stabilizer(Centr 1 & DPhA) in aged proplnts contg no otherbrominatablematerials, such as acardites, urethanes, phenols, p-nitromethylaniline and salicylates). Accdg to Apatoff & Cohen(Ref 37), the US Military Standard Method 217.2.1 known as "Available Stabilizer and described in Ref 34, depends on soly of dibromoethylcentralite in hot 47.5% alcohol as a means of separating it from tetrabromodiphenylamine ppt. After diluting the filtrate with w and heating the soln for several hrs on a water-bath(while a stream of air is directed on the surface of liq to assist the evapn), the dibromocentralite precipitates and is filtered off & weighed. It has been found difficult to obtain quantitative recovery of Centr by this method because of failure of the dissolved Centr 1 to completely precipitate and coagulate during heating on the water bath. It appears also that the concn of alc(47.5%) and temp of soln are critical in Method 217.2.1

In view of the inadequacy of the above method, Alpatoff & Cohen developed at the lab of Frankford Arsn, the following method, which is claimed to be rapid and accurate:

a)*Preparation of Sample.* Same as in opn(a) of (A)

b)*Distillation.* A 5g(weighed to within 0.2mg) sample of ground proplnt is transferred to a 1-l balloon flask,and, after adding 100ml of distd w & 100ml of 30% NaOH soln, the flask is closed with a two-hole stopper, provided with a stream inlet tube and a goose-neck tube ca 20cm high & 11mm OD. The latter tube is connected to condenser, which is provided at the other end with an adapter inserted in a 750-ml Erlen fl (receiver) contg 25ml of distd w. After connecting the inlet tube of the flask to a steam generator(either a 2-l balloon steam generating flask or a low -pressure steam line), the distn is conducted (without use of auxiliary heating of the flask contg proplnt) until,(in case of proplnts contg 4-5% of Centr or 1-3% of DPhA), 450-500 ml of liquid is collected. Then the steam generator is disconnected, the receiver is removed, 5g of Na chloride is added to the distillate and it is transferred to a 1 liter separatory funnel. The condenser, the goose-neck tube and adapter are rinsed with ca 60ml of ether and the rinsings are transferred to the separatory funnel

c)Extraction. The funnel is stoppered, shaken vigorously for several mins and the aqueous layer is drawn off into the 750-ml receiver flask, whereas the ether extract is transferred to a 200ml volumetric flask. The aq layer is transferred back the the separatory funnel for the 2nd extraction with 60ml ether. This extract is also transferred to the 200ml vol flask and the aq layer to the separatory funnel. After the 3rd extraction, the contents of the 200ml flask is made up to the mark with ether

d)Determination of DPhA by Gravimetric Bromination. One half(100ml) of the above ether extract is pipetted into a 250ml beaker, while the other half is reserved for opn (e) which follows. After placing the beaker on a closed water-bath, bromine is added drop by drop until a slight excess(which is indicated by appearance of light reddish-brown color) is present(ca 0.6ml is required for each percent of Centr & DPhA). Then the beaker is swirled, the soln is allowed to come to a boil and the beaker is immediately removed from the top of the bath. The rest of the ether is evapd by a current of dry air just to disappearance of ether odor, because prolonged evapn after removal of ether will yield low results. The residue in the beaker is heated to boiling with 40ml of 95% alc and the exact time is noted. Then, 40ml of dist w is added and the beaker is allowed to remain on the bath for exactly 10mins from the time noted, after which the hot soln is filtered thru a tared 30ml fritted glass crucible of medium porosity. The ppt on the crucible consisting of tetrabromo-DPhA is washed, first with ca 50ml of boiling 47.5% alc, and then with distd w. This is followed by drying at $105 \pm 2^{\circ}$ for 1 hr, cooling in a desicator and weighting. These opns are repeated until the wt between weighings at 2hr interval is less than 0.5mg

The % of DPhA is calcd from the formula: $(34.90 \times A \times 2)/W$, where A=increase in wt of crucible and W=wt of sample, corrected for total volatiles

e)Determination of Total Volume of Sodium Thiosulfate Equivalent. The remaining 100ml of ether extract[ see opn (d)] is transferred to a 250ml beaker, followed by rinsing the flask with

a few mls of ether. After evapg the ether [which could be done concurrently with the brominated portion of opn (d)], the residue is dissolved in glac AcOH, and the soln is transferred quantitatively to a 100ml vol flask. Then the beaker is rinsed with several portions of AcOH and the rinsing added to the contents in the flask. The flask is filled to the mark with AcOH and, after mixing, exactly 50ml of soln is transferred to a 250ml iodine titration flask, and, after cooling the soln to 20± 2°, 25ml of std 0.2N bromate-bromine soln is added. Further procedure is the same as in opn (c) of A, but calcn is different, because here is detd the value C, which is the mls of normal Na thiosulfate soln equivalent to the sum of brominated stabilizers. It is equal to (A-B) x N x 4, where A=ml of Na thiosulfate required for blank; B=ml of Na thiosulfate required to titrate the liberated iodine in the soln contg the brominated sample and N=normality of Na thiosulfate soln

Centr 1 is calcd by converting the % of DPhA detd in opn (d) of (A) to its equivalent volume of normal Na thiosulfate soln and subtracting this value from the vol of normal Na thiosulfate soln equivalent to the sum of the brominated stabilizers as obtained in opn (e) of (B). If D(mls of normal Na thiosulfate soln equivalent to DPhA in sample) is equal to: (%DPhA x W)/2.115, then % Centr 1 is equal to [6.71(C-D)]/W, where C=ml of normal Na thiosulfate soln equivalent to the sum of the stabilizers in sample and W=wt of sample corrected for total volatiles

*Note:* If instead of Centr 1, Centr 2(Methylcentralite) is a component of the proplnt, the calcn would be:

%Centr 2= [6.01(C-D)]/W

Swedish requirements and test for Centr 1 are given in Ref 33a. They include: appearance solidification pt(72°), boiling pt(326°), matter insol in ether-alc, ash, moisture and reaction (whether acidic or alkaline)

(Analytical procedures were reviewed by Mr N.Liszt of PicArsn)

*Refs:* 1)J.Tafel, Ber **25**, 412-13(1892)(Color reaction for detection of Centr 1; rose-red color is produced when a few crysts of $K_2Cr_2O_7$ are added to a small sample dissolved in concd $H_2SO_4$) 2)H.Lécorché & P.Jovinet, MP **23**, 69-78(1928)(A rather complicated and tedious method of quantitative detn of Centr 1 when in mixts with NG) 3)J.Goujon, MAF **8**, 837-902(1929) & its Ger translation in SS **26**,217,261,289,330, 361,400(1931)(An improved Taliani test for detn of stabilizing action of various substances including Centr 1) 4)H.Levenson, IEC, AnalEd **2**, 246-7(1930) [Detn of Centr 1 in double-base proplnts by extracting it(together with NG) with ether, evaporating the ether, dissolving the extracted material in alcohol and treating the soln with std bromine-bromate soln in presence of HCl] 5)O.C.Ellington & H.B.Beard, JACI **50**, 151T(1931) & CA **25**, 3485(1931)(Modification of Levenson's method: purified $CCl_4$ is used as solvent instead of alcohol; the advantage results from the fact that $CCl_4$ is non-reactive to bromine) 6)Marshall **3**(1932), 219(Color reactions for products from Centr 1 during aging of double-base proplnts) 7)O.Turek, Vojensko-TechnickeZpravy (Prague) **9**, 73-5 & 96(1932); CA **26**, 4953(1932) (Modification of bromometric method of detn of Centr 1 and critical review of methods of Levenson and Ellington & Beard) 7a)K.Masaki, BullChemSocJapan **7**, 353-62(1932) & CA **27** 904(1933)(A spectrochemical study of reaction products betw Centr and gaseous $NO_2$) 8)M. Tonegutti, SS **32**, 300-5(1937) & CA **32**, 1099 (1938)(Detn of stability of smokeless proplnts contg Centr 1, DPhA or Acardite by methods of Taliani and of Thomas. The Thomas method was found to be more reliable) 9)W.H.Brown, SocChemIndVictoria, Proc **38**, 42-6(1938) & CA **33**, 6597(1939)(Volumetric bromination method of detn of Centr 1; the procedure is similar to that of Ellington & Beard) 10)Thorpe **4**(1940), 521(A brief description of procedure for detn of Centr in proplnts developed by Levenson)(See Ref 4)(Also estimation of nitrosamine present in aged proplnts) 11)R.B.Corey et al, OSRD Rept **1103**(1942) and **1558**(1943)(Spectrophotometric investigations of double-base proplnts contg Centr 1) 12)Kast-Metz(1944), 167 [Colorimetric reactions for detecting Centr 1 and other tetrasubstituted ureas, such as Centr 2. A rose-red coloration is produced when a very dil(1:100) soln in concd $H_2SO_4$ is treated with a few grains of powdered $K_2Cr_2O_7$ or $PbO_2$(Tafel Reaction). An intense red coloration is obtained when Centr is treated with a very small quantity of K or Na nitrite in $H_2SO_4$ soln(Desvergnes Reaction)] 13)Kast-Metz(1944), 271-2(Qualitative detn of Centr 1 in proplnts); 289-95(Quantitative detn of Centr 1 in proplnts); 328-30(Detn of Centr 1 in Celluloid) 14)L.Pauling et al, OSRD Rept **4820**(1945) [A modified volumetric bromination procedure which employs glac AcOH as the organic solvent for the sample to be brominated,

and combines the advantges of $CCl_4$ & alcohol procedures(See Refs 4 & 5) in that the reaction is carried out in a one-phase system which is inert to bromine] 15)L.Pauling et al, OSRD Rept **5967**(1945), 16(Spectrophotometric data for Centr 1 and its transformation products formed during aging of double-base proplnts) 16)T.D. Waugh et al, IEC, AnalEd **18**, 636-7(1946) (Improved volumetric-bromination for detg Centr 1 in smokeless proplnts. Methylene chloride is used to extract the stabilizer from proplnt and glac AcOH as the solvent in bromination) 17)Coll, "Summary Technical Report of Division 8, NDRC," Vol 1, Washington, DC(1946), 124-5(A brief description of bromination procedures using $CCl_4$ and alcohol as solvent for the extract) 18) S.Weisberger, PATR **1662**(1947) [Development of chromatographic method for detg Centr in the 81mm mortar proplnt contg NC(13.25% N) 52.15, NG 43.00, DEtPh 3.00, K sulfate 1.25 & EtCentr 0.60%] 19)A.M.Soldate & R.M.Noyes, AnalChem **19**, 442-4(1947)(X-ray diffraction spectra for Centr 1) 20)I.S.Hirschhorn, AnalChem **19**, 880-2(1947) [Rapid method of detn of Centr 1 & NG in rocket proplnts. Both ingredients are extracted with 84% AcOH and then Centr is detd by bromination method of Waugh et al(See Ref 16)] 20a)T.C.J. Ovenston & C.A.Parker, JSCI **66**, 394-5(1947) (Detn of nitrosamine content of proplnts stabilized with Centr 1) 21)F.Pristera, PATR **1691**(1948) [Modification of chromatographic method described in PATR 1662(See Ref 18) to be applied to proplnts contg K nitrate instead of K sulfate] 22)T.C.J.Ovenston, JSCI **68**, 54-9(1949) & CA **43**, 5593(1949)(Chromatography in an explosives laboratory) 23)T.C.J.Ovenston, Analyst **74**, 344-51(1949) & CA **43**, 8137(1949)(Chromatographic detn of Centr 1 in proplnts) 24)W.A. Schroeder et al, IEC **42**, 539-46(1950) (Chromatographic-spectrographic method for detn of compds formed during accelerated aging of double-base proplnts contg Centr 1; color reactions with ceric sulfate reagent) [See also IEC **41**, 2822(1949)] 25)V.R.Grassie et al, CanJRes **28B**, 468-84(1950) & CA **45**, 3594(1951) (Preliminary tests on possible new stabilizers for NC, as compared with standard stabilizers, such as Centr 1) 26)G.Sifre, MP **35**, 382-6 (1953) & CA **49**, 9448(1955)(Polarographic detn of Centr 1 in proplnts; the method is fairly rapid, but precision is no better than 2%) 27)J.O.Watts & H.Stalcup, AnalChem **29**, 253-4(1957) & CA **51**, 5424(1957) [An azeotropic mixt of pentane & methylene chloride(2:1) is used to extract Centr 1 & NG from NGu type of proplnts, such as Cordite -N; NGu is much less sol in this mixt than in methylene chloride alone) 28)J.Grodzinski, BullResearch-CouncilIsrael **7A**, 21-8(1957) & CA **52**, 7020-1(1958)(Colorimetric detn of Centr in proplnts by means of ceric molybdate soln) 29)M.Laccetti et al, GenLabRept **57-HI-519**, PicArsn, Dover, NJ(1957)(Development of spectrophotometric method for simultaneous detn of "actual" Centr 1 and its primary degradation products in aged proplnts) 30)L. Marvillet, MP **40**, 273-87(1958) & CA **54**, 25825 (1960)(Chromatographic detn of Centr 1 and of other ingredients of proplnts) 31)M.A.Laccetti & M.Roth; JANAF-PACSP Second Cooperative Test Program on Stabilizers, PicArsnTechMemo No **GL,-6-59**(1959)(Evaluation of methods for the analysis of DPhA, EtCentr and some of their degradation products) 32)M.Laccetti, FREL TechMemo No **ACS-2-59**, PicArsn, Dover, NJ(1959) (Spectrophotometric method for the detn of admixtures of DPhA & EtCentr in proplnts) 33) M.Roth et al, FREL TechMemo No **ACS-2-60**, (1960)(Interlaboratory detn of spectrophotometric factors for DPhA & Centr 1 and their primary degradation products) 33a)Anon, "Analytical Methods for Powders and Explosives", AB Bofors, Nobelkrut, Sweden(1960), 80-1 34) US Military Standard **MIL-STD-286A**(1961) (Propellants, Solid: Sampling, Examination and Testing); Method 202.2.2(Detn of EtCentr in newly manufd proplnts); Method 217.2.1(Detn of available stabilizer in aged proplnts) 35)PATR **2700** Vol 1(1960), pp A516 & A674 36)US Joint Army-Navy Specification **JAN-E-255** [Ethyl Centralite(Carbamite)] 37)J.Apatoff & J.Cohen, "Determination of Admixture of Diphenylamine and Ethyl Centralite in Propellants", Test Report **T62-15-1**, Frankford Arsenal, Philadelphia, Pa (1962)

**Centralite 1; Nitro Derivatives**

**Mononitrocentralites**, $C_{17}H_{19}N_3O_3$; mw 313.35, N 13.42%. Two isomers are known: *2-Nitrocentralite*, col crysts(from benz-ligroin), mp 56-7°; was prepd in small yield by condensation of N-ethyl-2-nitrocarbanilyl chloride with N-ethylaniline(Refs 7 & 8) and *4-nitrocentralite*, yel, viscous oil which could not be induced to crystallize; was prepd by condensation of N-ethyl -4-nitrocarbanilyl chloride with N-ethylaniline (Refs 7 & 8)

Lécorché & Jovinet(Ref 5), by nitrating Centr 1(dissolved in AcOH) with 1 mole nitric acid prepd a product, melting at 43° which was

probably an impure nitrocentralite; it was not properly identified

**Dinitrocentralites,** $C_{17}H_{18}N_4O_5$; mw 358.35, N 15.64%. One isomer: *4,4'-Dinitrocentralite,* $OC[N(C_2H_5)C_6H_4(NO_2)]_2$, bright yel crysts (from alc), mp 147°(by Maquenne block); was prepd by *nitrating Centr 1 with concd nitric or* with mixed nitric-sulfuric acids(Refs 1,2,3,4 & 6). A product melting at 144° was prepd by treating Centr 1 with nitrous fumes(Refs 1,p 181)

**Trinitrocentralites,** $C_{17}H_{17}N_5O_7$, mw 403.35, N 17.36%. One isomer, presumably: *2,4,4'-Trinitrocentralite,* crysts(from absol alc), mp 151.5-152.3°, was prepd by nitrating 4,4'-dinitrocentralite with mixed nitric-sulfuric acid, as described in Ref 7,p 948

**Tetranitrocentralites,** $C_{17}H_{16}N_6O_9$; mw 448.35, N 18.75%. One isomer: *2,4,2'4'-Tetranitrocentralite,* $OC[N(C_2H_5).C_6H_3(NO_2)_2]_2$, crysts, mp 178°(by Maquenne block) is known. It can be prepd by nitrating Centr 1 with fuming nitric or with concd mixed nitric-sulfuric acid(Refs 1,2 & 6). A small quantity of tetranitro compd was reported to have been obtained on treating Centr 1 with nitrous fumes(Ref 3)

**Hexanitrocentralites,** $C_{17}H_{14}N_8O_{13}$; mw 538.35, N 20.82%. One isomer: *2,4,6,2',4',6'Hexanitrocentralite,* $OC[N(C_2H_5).C_6H_2(NO_2)_3]_2$, crysts, mp 248°(by Maquenne block) is known. It was prepd by nitrating Centr with concd nitric acid and oleum as described in Ref 4. Its soly in grams per 100g of solvent at 25.5° is: EtOAc 0.839, $Me_2CO$ 1.055, absol EtOH 0.029, MeOH 0.067, $C_6H_6$ 0.054, $CHCl_3$ 0.339, $Et_2O$ 0.024, $CS_2$ 0.007, $CCl_4$ 0.028, $C_7H_8$ 0.031 & $C_5H_5N$ 12.65 (with decompn). Its expl props were not detd

Accdg to Thorpe(Ref 6), nitration of Centr 1 did not produce Hexanitrocentralite

*Refs:* 1)Beil **12**, [238] 2)M.Giua & G.Guastalla, AttiAccadTor **60**, 75(1925) & CA **19**, 2133(1925) 3)A.Apard, MP **22**, 181-2 & 187-9(1926) 4)L. Desvergnes RevChimInd **37**, 41(1928) & CA **22**, 1963(1928) 5)H.Lécorché & P.Jovinet, *MP* **23**, 148-9(1928) 6)Thorpe **4**(1940), 521 7)P.E.Wilcox, & W.A.Schroeder, JOC **15**, 946-8(1950) 8)W.A. Schroeder et al, IEC **42**, 545(1950)

**Centralite 1; Transformation Products Formed During Aging of Propellants Containing It.** Aging of proplnts contg Centr 1, its stabilizing action on NC & NG,and transformation products formed during aging are discussed in Refs 1-7 & 9-10. Nitro compds of Centr 1, some of them formed during aging of proplnts, are described here under Centralite 1, Nitro Derivatives of

One of the most important investigations of transformation products of Centr 1, formed during aging of some double-base proplnts, was conducted during WWII and CALTECH under direction of Dr L.Pauling(Ref 4). Abstract of this work is given in Ref 5 and an abbreviated version in Ref 9. Some of the transformation products were synthesized, as described in Ref 8. The work on transformation products of Centr 1 done at PicArsn is briefly described in Refs 10 & 11(See also Centralite 1, Analytical Procedures)

Following is a brief description of the work done in the US during WWII:

Two double-base proplnts were investigated, one was *Cordite JP 76,* a "solvent" process compn of high content of Centr. Its approx compn was: NC(12.24% N) 49.6, NG 41.4 & EtCentr 9%. The other, *RPL 142*(Radford Pilot Lot No 142), was a "solventless" process compn contg a small amt of Centr. It compn was: NC(13.22% N) 59.0, NG 40.0 & EtCentr 1%. Artificial aging of these proplnts was produced by heating samples in vented metal cans at 65° & 75° for varying periods of time up to 2yrs. The samples were periodically removed, cut into slices 0.1 to 0.15mm in thickness by means of a sliding microtome, weighed and extracted for 2-3hrs with anhyd ether or methylene chloride in a Soxhlet apparatus, Extracts in ether were first evapd to remove the solvent(because it is a strong eluent) and the residue was taken up in 1:1 benz-ligroin. Extracts in methylene chloride were either diluted directly with ligroin or partly concentrated and then diluted with ligroin. Aliquot portions of the resulting solns were taken for chromatography. The absorbent used in all of the chromatographic experiments was a 2:1 mixt of silicic acid(Merck Reagent) and Celite 535(of Johns Manville Corp). The apparatus was the same as for detn of transfomation products of DPhA described by W.A.Schroeder et al, IEC **41**, 2818(1949). The quantity of each compd isolated on chromatographic column was estimated spectrophotometrically in absolute alc by measuring the optical density at the wave length of maximum absoprtion(Refs 4 & 9)

Quantitative analyses were made on samples which originally contained ca 100mg of Centr. The chromatographic-spectrographic method can detect quantitatively less than 0.1mg of substance

When the chromatographic method was applied to selected samples of each proplnt, it was possible to isolate about 40 compds, of which 17 were definitely identified, 3 tentatively identified and the remainder could not. The compds identified could be classified as follows:

a)Compounds in which the urea structure is still present. These included: 4-nitro-, 4,4'-dinitro- and only small amts of 2,4,4'-trinitro- and 2-nitroethylcarbanilides

b)Compounds in which the urea structure is split. These included N-nitroso-N-ethylaniline & 4-nitro-N-nitroso-N-ethylaniline and traces of 4-nitro-N-ethylaniline, 2-nitro-N-ethylaniline, 2,4-dinitro-N-ethylaniline, N-ethylcarbanilide, 4-nitroaniline & 4-nitrophenol. Certain other identified compds, such as 4-nitro-N,N-diethylaniline, probably were derived from traces of N,N-diethylaniline which could be detected in commercial Centr 1

c)Compounds tentatively identified. These were probably degradation products of NG, because they resembled some of the substances isolated from old solns of NG

Besides the identified products, there were isolated several transformation products, the structure of which were not detd. Another undetermined problem was the fate of portion of Centr 1(ca 50%) which was apparently depleted from the proplnts and could not be accounted for in terms of Centr derivs in the extract

Behaviors of proplnts JP 76 & RPL 142 on heating at 65° were not identical. Although the heating of samples of JP 76 continued for 107 weeks, no blistering or evolution of $NO_2$ was observed. On the other hand, samples of RPL 142 became blistered and evolved $NO_2$ after 93 weeks of heating. While in JP 76, N-nitroso-N-ethylaniline was the major primary transformation product of Centr 1 and 4-nitrocentralite was the minor product, the situation was reversed in RPL 142, where 4-nitrocentralite predominated. Furthermore, the rate at which Centr 1 disappeared from JP 76 was about 5 times as great as that at which it was depleted from RPL 142. This was due to the greater initial amt of Centr in JP 76

Only three samples of RPL 142 proplnt were heated at 75° and, of these, two became blistered and evolved $NO_2$ after 33 weeks, while the 3rd sample remained unchanged(except for color) even after 41 weeks of heating(Refs 4,5, 6 & 9)

Transformation products of Centr 1 isolated at PicArsn(Refs 10 & 11) from stored double-base proplnts included: nitro- and nitroso- derivs of Centr and products formed on its cleavage by acids. These included N-ethylaniline which, being very reactive, combined immediately with nitrous acid to form N-nitroso-N-ethylaniline which was present in large amt. This product was removed together with 2-nitro-N-ethylaniline from degradation products by steam distn. Some derivs of Centr 1 isolated from aged proplnts possessed stabilizing props

(The section on Transformation Products was reviewed by Mr. N.Liszt of PicArsn)

*Refs:* 1)H.Lécorché & P.Jovinet, MP **23**, 69 & 147(1928); CA **22**, 3779(1928) & **23**, 2296(1929) {Transformation products of Centr 1 formed in double-base proplnt [containing NC(12% N) 66, NG 27 & Centr 7%] after 4yrs of storage at 50°, consisted mostly of p-nitrophenylethylnitrosamine and mononitrocentralite. The 1st was volatile with steam while the 2nd was not} 2)Marshall **3**(1932), 211-12 [Centr 1 in a proplnt stored at RT's or above, gradually becomes hydrolyzed, yielding $CO_2$ and N-ethylaniline, the latter gives a slightly basic reaction and can neutralize any acid present. Ethylaniline can also combine with NO to form ethylphenylnitrosamine, $H_5C_2.N(NO).C_6H_5$, which is further converted into nitronitrosamine and into nitroethylphenylamines. Some nitrocentralites are also formed. As only a small quantity of N-ethylaniline is present at any one time, it does not seriously attack the nitric esters and Centr 1 can therefore be used in proplnts contg NG] 3)Thorpe **4**(1940), 521 [Stabilizing action of Centr 1 is explained by the theory that as soon as the proplnt contg NC-NG-Centr 1 becomes acidic, the Cent is hydrolyzed to ethylaniline which reacts with any nitrous acid present to form phenylethylnitrosamine. Any nitric acid formed during the decompn of the proplnt is absorbed(at least partly) by Centr with the formation of a mononitrocentralite. By estimating the amt of nitrosamine present it is possible to estimate approximately the extent of "aging" of a proplnt. For this detn 2g of the finely divided proplnt can be digested for 24hrs at RT with 100ml of alc, 2ml of soln placed in a test tube, 5ml of alc added, followed by 1ml of a 1% soln of α-naphthylamine & 5 drops of HCl. The closed tube is then placed in a water bath, heated to 60° and, after 10mins the color of

liquid is compared with a standard] 4)L. Pauling et al, OSRD Rept **5967**(1945)(Transformation products of Centr 1 during aging of various double-base proplnts) 5)Coll, "Summary Technical Report of Division 8, NDRC," Vol 1, Washington, DC(1946)(Resumé of OSRD 5967) (See Ref 4) 6)C.A.Parker, JSCI **67**, 434-6(1948) (Chromatographic separation of some transformation products of Centr 1 formed during aging of Cordites. These products include N-nitroso-N-ethylaniline and its nitro derivs) 7)A.G.García-Gutiérrez, Ion(Madrid) **9**, 165-7 (1949) & CA **43**, 6825(1949)(A review of stabilization of smokeless proplnts and materials used for stabilizers. These included Centr 1 and Centr 2. It was found that both Centralites form analogous transformation products in aged proplnts, except that nitration of Centr 2 proceeds more easily and higher nitro derivs can be formed) 8)P.E.Wilcox & W.A.Schroeder, JOC **15**, 944-9(1950)(Synthesis and detn of props of some derivs of urea and of Centr, which were formed during accelerated aging of double-base proplnts. Among the compds prepd and investigated were mono-, di- and trinitro- centralites. They are described here under Centralite 1, Nitro Derivatives) 9)W.E.Schroeder et al, IEC **42**, 539-46(1950) (Transformation products of Centr 1 formed in double-base proplnts during accelerated aging) 10)M.Laccetti, GenLabRept **57-HI-519**, PicArsn, Dover, NJ(1958) 11)M.Roth et al, FREL TechMemo **ACS-2-60**, PicArsn, Dover, NJ(1960)

**Centralite 2 or Methylcentralite**(US); *Mollit 2* (Ger trade name for product used as a plasticizer); *N,N'-Dimethylcarbanilide or N,N'-Dimethyl-N,N'-diphenylurea,* $OC[N(CH_3)\cdot C_6H_5]_2$; mw 240.29, N 11.66%; crysts(from alc), mp 121.5°, bp 350°(Refs 1,13 & 15); difficultly volatile with steam(Ref 13); heat of combustion at const vol, $Q_c^v$, 8081cal/g or 1941.7kcal/mole & at const pressure, $Q_c^p$, 8087cal/g or 1943.1kcal/mole; heat of formation at const vol, $Q_f^v$, 66.5cal/g or 16.0kcal/mole & at const pressure, $Q_f^p$, 89.4cal/g or 21.5kcal/mole (Refs 19 & 20); calorific constant, h, is -23.8 cal per 0.01g of Centr 2, which corresponds to calcd calorific value at const pressure of 1930kcal/mole at 17°, vs experimental value of 1948.5kcal/mole(Ref 16). Centr 2 is insol in w, sol in alc(7g in 100ml of 96% alc at RT); sol in ether & benzene(Refs 1, 13 & 15). Its soly in 100g NG is 13.0g at 18° & 19.4g at 23°(Ref 8, under Analytical Procedures)

Centr 2 was first prepd by Michler(Refs 1 & 2) on passing phosgene thru boiling dimethylaniline. Michler & Zimmermann(Refs 1 & 3) prepd it by heating methylphenylcarbamyl chloride with methylaniline & some Zn dust. Dains et al(Refs 1 & 4) prepd it by heating equimolecular quantities of N-methyl-N,N'-diphenylthiourea with methylphenylcarbamyl chloride at 150°. Mailhe(Refs 1 & 7) prepd it by passing vapor of N-methylformanilide(yel, viscous oil, bp 286°) over finely divided nickel at 380-400°

Gelatinizing power of Centr 2 was discussed by Davis(Refs 6 & 11) and its stabilizing power was investigated by Rinkenbach(Ref 12), Grassie et al(Ref 17) and Desseigne & Tranchant(Ref 21)

*Uses:* Centr 2 can be used for the same purposes as Centr 1(Refs 6 & 22) but it is sometimes not as desirable due to its rather high mp (121-121.5°) and because it is not as good a gelatinizer for NC as Centr 1(Ref 6). It was used during WWI in some rifle proplnts(Ref 11), and was proposed as an anti-knock additive to motor fuels(Ref 14). It can also be used as a coating agent of proplnts(Ref 22)(See also Centralite 2, Analytical Procedures; Centralite 2, Nitro Derivatives of and Centralite 2 Transformation Products Formed During Aging of Propellants Containing It)

*Refs:* 1)Beil **12**, 418, (251) & [236] 2)W. Michler, Ber **9**, 716(1876) 3)W.Michler & R. Zimmermann, Ber **12**, 1166(1879) 4)F.B.Dains et al, JACS **38**, 134(1916) 5)H.Kast, "Spreng- und Zündstoffe", Vieweg, Braunschweig(1921), 185(Some props of Centr 2) 6)T.L.Davis, IEC **14**, 114(1922)(Gelatinizing power of Centr 2 for NC in single-base proplnts is lower than that of Centr 1 or Butylcentralite) 7)A.Mailhe, CR **176**, 904(1923) & JCS **124** I, 458(1923)(New method of prepn of Centr 2) 8)Stettbacher (1933), 197(Centr 2 & Centr 1 were investigated in Germany ca 1907 as possible stabilizers for NC in smokeless proplnts) 9)T.Urbański, RoczChem **13**, 399(1933) & **28**, 27(1943)(Binary mixts of Centr 2 with expls, such as HNMnt & PETN have ,correspondingly, eutectic points of 77.4° & 102.7°) 10)Thorpe **4**(1940), 521 (Some props of Centr 2) 11)Davis(1943), 319 (Centr 2 was widely used during WWI as a deterrent in rifle proplnts designed to produce very high velocities) 12)W.H.Rinkenbach, PATR **1480**(1944)(Investigation of various US

single-base proplnts has shown that Centr 2 is as effective as DPhA in stabilizing FNH-M1 proplnt, but not effective for FNH-M3 and Pyro proplnts. It is, however, a better stabilizer than methylacardite or carbazole) 13)Kast-Metz (1944), 165-6(Some props of Centr 2) 14)G.B. Banks, USP 2373372(1945) & CA **39**, 3423 (1945)(Addn of small quantity, such as 0.1%, of Centr 2 to motor fuels improves their antiknock properties) 15)Pérez Ara(1945), 423 (Some props) 16)J.Taylor et al, JPhysCollChem **51**, 590(1947)(Some thermochemical props) 17)V.R.Grassie et al, CanJRes **28B**, 468(1950) & CA **45**, 3594(1951)(Comparison of stabilizing props of various stabilizers including Centr 2) 18)W.A.Schroeder et al, AnalChem **23**, 1743 (1951)(UV & Visible spectra of Centr 2) 19)L. Médard & M.Thomas, MP **34**, 423-4 & 440(1952) (Some thermochemical data) 20)L.Médard, MAF **28**, 480(1954)(Same info as in Ref 19) 21)G. Desseigne & J.Tranchant, CR **239**, 769(1954) & CA **49**, 11285(1955)(Gelatinizing power for NC of Centr 2 in comparison with other substituted ureas and urethanes) 22)US Military Specification **MIL-M-19719**(1960),p 5

**Centralite 2, Analytical Procedures.** Colorimetric & other qualitative tests for Centr 2 are similar to those described under Centralite 1, Analytical procedures(See also Refs 1, 2 & 3). Chromatographic detn is described in Ref 4 and analysis by IR spectroscopy in Ref 6. In Ref 5 are given UV and visible absorption spectra of Centr 2 and in Ref 7 described detn of its UV absorption spectra

Centralite 2 intended for use in US proplnts(Ref 9) shall be supplied either in the form of white lumps(Class 1) or powder(Class 2), consisting essentially of dimethyldiphenylurea. Both classes shall be free from grit or visible impurities and meet the following other requirements:

I)*Solidification Point* - 120.5° to 122°, and the substance shall melt to a bright, clear liquid free from scum and deposit. Test shall be conducted in an apparatus and in the manner similar to proced (I) described under Centralite 1, Analytical Procedures, except that no water is placed in the outer bottle, just air

II)*Volatile Matter* - 0.20% max. Same detn as for Centr 1, except that heating shall be for 3hrs at 100-105°

III)*Ash Content* - 0.1% max. Same test as for Centr 1

IV)*Amines* - 0.20% calcd as methylamine when detd using the proced IV for secondary amines described under Centr 1 but calcg % methylaniline from the formula: $[10.7(V_1-V_2)N]/W - A \times 1.78$, where $V_1$ = ml of NaOH soln required to titrate blank; $V_2$ = ml of NaOH soln required to titrate sample; N=normality of NaOH soln; W=wt of sample and A=% acidity as AcOH

*Note:* This method is not specific for amines but will detect other groups such as OH

V)*Acidity* - shall not exceed 0.006% acid calcd as AcOH. A 20g sample dissolved in 100ml of benzene is extracted with three successive 25ml portions of boiled w and the combined extract titrated with 0.02N NaOH soln using phpht as indicator. A blank detn is run concurrently and % AcOH is calcd from the formula: $[6.0(V_1-V_2)N]/W$, where $V_1$ = ml of NaOH soln required to titrate sample; $V_2$ = ml of NaOH soln required for blank; N=normality of NaOH soln and W=wt of sample

VI)*Hydrolyzable Matter* - shall be absent when tested as described under Centr 1

VII)*Particle Size.* Class 2(powder)-a min of 100% of the material shall pass thru US Std No 50(297 micron) sieve conforming to US Spec RR-S-366. The test is conducted in the same manner as described for Centr 1

*Determination of Centralite 2 in Propellants* may be conducted as described in Methods A and B under Centralite 1, Analytical Procedures, except that the formulas for calcns are different and are given under Centr 1

Swedish requirements and tests are given in Ref 8. They include: appearance, solidification pt(121°),boiling pt(350°), matter insol in eth-alc, ash, moisture and reaction(whether acidic or alkaline)

*Refs:* 1)B.T.Dewey & A.H.Gelman, IEC, AnalEd **14**, 361(1942) & CA **36**, 3750(1942) (Color reactions of Centr 2 with $H_2SeO_3$-$H_2SO_4$ solns) 2)Kast-Metz(1944), 167(Color reactions for detection of Centr 2 are identical with those described for Centr 1) 3)Kast-Metz(1944), 292-3 (Gravimetric and volumetric methods for detn of Centr 2 in proplnts are similar to those for Centr 1) 4)T.C.J.Ovenston, Analyst **74**, 344-51(1949) & CA **43**, 8138-9(1949)(Chromatographic investigation of proplnts using various stabilizers, among them Centr 2) 5)W.A.Schroeder et al, AnalChem **23**, 1740-7(1951) & CA **46**, 5434(1952) (Detn of ultraviolet and visible absorption spectra of several stabilizers, among them Centr 2, in ethanol) 6)F.Pristera, AnalChem **25**, 844

(1953) & CA **47**, 9207(1953)(Analysis by infrared spectroscopy of proplnts contg various stabilizers among them Centr 2) 7)P.G.Grammaticakis, CR **248**, 244-7(1959) & CA **54**, 8277(1960)(Detn of UV absorption spectra of Centr 2) 8)Anon, "Analytical Methods for Powders and Explosives", AB Bofors, Nobelkrut, Sweden(1960), 80-1 9) US Spec **MIL-M-19719A**(1960) [Methylcentralite (For Ammunition Use)]

**Centralite 2; Nitro Derivatives**

*Mononitrocentralites*, $C_{15}H_{15}N_3O_3$; mw 285.29, N 14.73%; were claimed to be obtained by Moisak(Ref 3) on nitration of Centr 2 with nitric acid of 10-20% concn

**Dinitrocentralites**, $C_{15}H_{14}N_4O_5$; mw 330.29, N 16.96% One isomer, *4,4'-Dinitrocentralite*, $OC[N(CH_3).C_6H_4(NO_2)]_2$; crysts, mp 156-7° (by Maquenne block) is known(Refs 1, 2 & 4). It can be prepd by nitrating Centr 2 with 30-70% nitric acid(Ref 3)

**Trinitrocentralites**, $C_{15}H_{13}N_5O_7$; mw 375.29, N 18.66%. One isomer, *x,x,x-Trinitrocentralite*, was claimed to be prepd by nitrating Centr 2 with concd nitric acid(Ref 3)

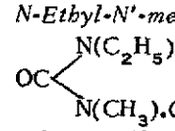
**Tetranitrocentralites**, $C_{15}H_{12}N_6O_9$; mw 420.29, N 20.00%. One isomer, *2,4,2',4'-Tetranitrocentralite*, $OC[N(CH_3).C_6H_3(NO_2)_2]_2$; small yel crysts, mp 192° is known. It was prepd by nitrating Centr 2 with mixed nitric-sulfuric acid (Refs 1, 2 & 4). Its expl props were not detd

**Hexanitrocentralite**, $C_{15}H_{10}N_8O_{13}$; mw 510.29, N 21.96%. One isomer of unknown structure is known; yel crysts, mp >300°(with sublimation); was obtained on adding slowly a soln of Centr 2 in concd sulfuric acid to a mixt of concd nitric acid with oleum, preheated to 50-60° (Ref 2,pp 185-6). Its expl props were not detd

*Refs:* 1)Beil **12**, [236] 2)A.Apard, MP **22**, 183-7(1926) 3)I.E.Moisak, TransKirovInstit-Kazan'(Russia), No **3**, 159-64(1935) & CA **29**, 4177(1935) 4)Thorpe **4**(1940), 521

**Centralite 2; Transformation Products Formed During Aging of Propellants Containing It.** Accdg to A.G.García-Gutiérrez, Ion(Madrid) **9**, 165-7(1949) & CA **43**, 6825(1949), Centr 2 forms in aged proplnts, transformation products analogous to those formed from Centr 1, except that nitration of Centr 2 proceeds easier and higher nitro derivs can be formed(See also Centralite 2, Nitro Derivatives)

**Centralite 3 or Ethylmethylcentralite**(US); *Mollit 3*(Ger trade name for product used as a plasticizer); *N-Ethyl-N'-methylcarbanilide or N-Ethyl-N'-methyl-N,N'-diphenylurea,*



; mw 254.28, N 11.02%; col crysts(from gasoline), mp 74°(Refs 1 & 2); wh pdr(by successive crystns from benz, acetone, methanol & chloroform) 60.5°(by Maquenne block)(Ref 4); $Q_c^v$ 8233cal/g or 2093.8kcal/mole and $Q_c^p$ 8247cal/g or 2094.4kcal/mole(Refs 4 & 5); $Q_f^v$ 101.6cal/g or 25.8kcal/mole and $Q_f^p$ 118.3cal or 30.1kcal/mole (Refs 4 & 5); Tavernier(Ref 7) gives $Q_f^v$ 118cal/g and $Q_f^p$ 143cal/g. It is insol in w; easily sol in alc or benz and diffc sol in ether(Ref 1)

Centr 3 was prepd by Dains et al(Refs 1 & 2) by two methods: a)Heating of equimolecular quantities of N-ethyl-N,N'-diphenylthiourea and methylphenylcarbamyl chloride at 150-160° or b)Heating a mixt of ethylaniline, methylphenylcarbamyl chloride and pyridine at 140°

Gelatinizing power of Centr 3 is discussed in Ref 6

*Uses:* Can be used for the same purposes as Centr 1, but is inferior to it

(See also Centralite 3, Analytical Procedures)

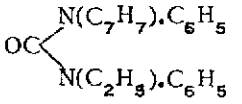
*Refs:* 1)Beil **12**, (253) 2)F.B.Dains et al, JACS **38**, 134(1916) 3)Kast-Metz(1944), 166 (Some props) 4)L.Médard & M.Thomas, MP **34**, 424 & 440(1952)(Some thermochemical data) 5)L.Médard, MAF **28**, 480(1954)(Same info as in Ref 4) 6)G.Desseigne & J.Tranchant, CR **239**, 769-71(1954) & CA **49**, 11285(1955)(Gelatinizing power of Centr 3 in comparison with other gelatinizers) 7)P.Tavernier MP **38**, 306 & 328(1957) & CA **51**, 15952(1957)(Some thermochemical data)

**Centralite 3, Analytical Procedures.** Accdg to Kast-Metz(1944), 167, color reactions of Centr 3 are identical with those described under Centr 1. Some gravimetric and volumetric procedures described in Kast-Metz(1944), 292-3 are applicable to detn of Centr 3 in smokeless proplnts. No other info is at our disposal

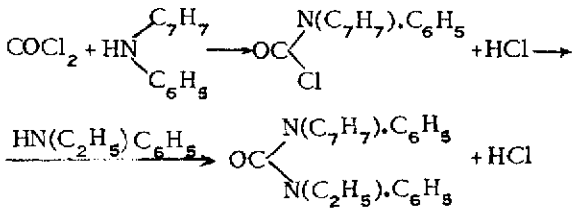
**Centralite 3, Nitro Derivatives.** No info at our disposal

**Centralite 3 Transformation Products Formed During Aging of Propellants Containing It.** No info at our disposal

In addition to Centralites 1, 2 and 3, there is also Centralite 4, which was prepd and investigated in France, and Butylcentralite, first described by Davis in 1922

**Centralite 4.** The name proposed by Tavernier for *Ethyltolylcentralite or N-Ethyl-N'-tolyl-N,N'-diphenylurea,*  ; mw 330.41, N 8.48%

Tavernier(Refs 2 & 3) gives the following props: mp ca 30°, $Q_f^v$ 112cal/g, $Q_f^p$ 138cal/g, specific mass 1.143g/cm³ at 300°K and specific volume 0.875cm³/g, but does not describe its method of prepn. Dr Walter(Ref 4) suggests to treat N-tolyl-aniline(in pyridine +ether) with phosgene, followed by heating the resulting chloride with N-ethyl-aniline. The following reactions take place:



*Uses:* No info at our disposal

*Refs:* 1)Beil-not found 2)P.Tavernier, MP **38**, 307 & 329(1956) & CA **51**, 15952(1957) 3)P.Tavernier, MP **39**, 270 & 294(1957) & CA **53**, 1715(1959) 4)H.Walter, PicArsn; private communication(1962)

**Centralite 4, Analytical Procedures.** No info at our disposal

**Centralite 4, Nitro Derivatives.** No info at our disposal

**Centralite 4; Transformation Products Formed During Aging of Propellants Containing It.** No info at our disposal

**Centralite, Butyl;** *N,N'-Dibutylcarbanilide or N,N'-Dibutyl-N,N'-diphenylurea,* $OC[N(C_4H_9).C_6H_5]_2$; mw 324.45, N 8.64%; wh pdr, mp ?. This compd was prepd and investigated in Germany and found to be suitable as a stabilizer and gelatinizer for smokeless proplnts(Ref 4). Accdg to Davis (Refs 2 & 3), it is a better gelatinizer than either the ethyl or methyl compd, because the heavier the alkyl group, the greater the gelatinizing power appears to be. Beil(Ref 1), Davis(Refs 2 & 3), Pérez Ara(Ref 4) and Schroeder(Ref 5) do not describe its method of prepn, but it was undoubtedly prepd in the same manner as other Centralites, except that ethyl and methyl groups of materials used for their prepn were replaced by n-butyl. For example, interaction of 1 mole of phosgene with 2 moles of n-butylaniline, would be one of the methods of prepn. Schroeder et al(Refs 5) who detd its UV & visible absorption spectra, did not prep the material but obtained it from one of the labs working under NDRC contracts. The purity of the sample is unknown, because its mp was not detd

*Uses:* It can be used in proplnts for the same purposes as other Centralites(Ref 2 & 3), but we could not find in the literature any formulations using it

*Refs:* 1)Beil **12**-not found 2)T.L.Davis, IEC **14**, 1140(1922) 3)Davis(1943), 319 4)Pérez Ara(1945), 423 5)W.A.Schroeder et al, AnalChem **23**, 1741 & 1743(1951)

**Centralite, Butyl, Analytical Procedures.** No info at our disposal

**Centralite, Butyl; Nitro Derivatives of.** No info at our disposal

**Centralite, Butyl; Transformation Products Formed During Aging of Propellants Containing It.** No info at our disposal

**Centralite RII.** A permissible expl contg AN 42, K perchlorate 20, TNT 14, Na oxalate 6 & NaCl 18%(Ref 1). Accdg to Thorpe(Ref 2) it was a Belgian expl contg AN 62, TNT 14, Na oxalate 6 & NaCl 18%

*Refs:* 1)Pepin Lehalleur(1935), 421 2)Thorpe **4**(1940), 556

**Centrifugal.** See Centrifuge and Its Applications

**Centrifugal Casting of Metals and Explosives.** Centrifugal casting of metallic objects(such as cylindrical bodies, railway car wheels, pipes, piston rings, gear blanks, etc) consists of pouring the molten metal into a mold which is rotating rapidly about its axis. It may be considered as a modified type of *pressure casting* which consists of making a casting with the aid of pressure upon the molten or highly plastic material in the die or mold(Refs 2,3,4,6,7 & 8 and numerous entries in CA's)

Railway car wheels were probably the first foundry products in the US to be centrifugally cast. The idea to do it was conceived in 1898 by J.C.Davis and the production began in 1902 at the East St Louis Works of American Steel Foundaries. During WWI experiments were conducted at the Buckeye Steel Casting Co on centrifugal castings of tubes and jackets for 75mm field guns, but the results were rather unsuccessful. Later on, extensive research

on manuf of gun tubes was carried out at Watertown Arsenal under the direction of Dr F.C.Langenberg, resulting in the development of a successful procedure(Ref 8)

In the Watertown Arsenal method, the metal is melted in batch lots of the required weight in high-frequency induction furnaces and poured into a horizontally mounted mold rotating at 1300rpm while it is cooled on the outside with water. The mold is made of heavy cast iron and machined inside to the desired shape of the exterior of the gun to be produced. The finished casting has a hollow core and can be easily bored out to the desired internal diam of the gun(Ref 3)(See also Ref 2a)

Application of centrifugal techniques to casting of HE charges was patented in 1913 by the Deutsche Sprengstoff AG(Ref 1). Although it was claimed that chges of high density and free of cavitation were produced by this method, no later work appears to have been done on this subject, until the investigations conducted by Clift at Picatinny Arsenal(Ref 5) on loading with Comp B the 57mm T188EIO HEAT shells. This type of shell was selected because it could not be loaded satisfactorily by conventional single-pour loading procedures and it was necessary to use a special two-pour method. In this rather slow method, Comp B was poured into the shell at 85° in two increments, the 1st at a depth of 1½" from the base of the shell and the 2nd(after puddling the 1st pour and assembling a riser), to within ½" of the top of the riser

Centrifugal loading of Comp B was conducted in a specially designed and constructed machine. Details of machine, capable of accommodating two 57mm shells, is shown in Figs 8,9,10,11,12 & 13 of Ref 5. While two shells(with risers inside and preheated to 80°) were in vertical position, Comp B(preheated to 92°) was poured into them thru plastic shrouds and funnels to the required level. Then the arm of the machine was rotated at 200 or 250rpm, and the cradles holding the shell assemblies were swung by centrifugal force outward to a horizontal position where they remained while rotation continued until the charges solidified. The time required for cooling and for total operation was not indicated in Ref 5

Shells loaded centrifugally at 200rpm gave slightly higher penetration on firing against mild steel targets, than those loaded by two -pour process, while shells loaded at 250rpm gave slightly lower results

*Refs:* 1)Deutsche Sprengstoff A-G, GerP 279526(1913) & CA **9**, 1995(1915)(Centrifigal casting of fusible expls) 2)M.vonSchwarz & A.Väth, Metallwirtschaft **8**, 891-9(1929) & CA **24**, 43(1930)(A review of centrifugal casting of metals) 2a)Hayes(1938), 192-3(Centrifugal casting of cannons) 3)C.R.Hayward, "An Outline of Metallurgical Practice", Van Nostrand, NY(1952), 619(Centrifugal method for casting gun barrels developed at Watertown Arsenal, Mass) 4)J.G.Henderson & J.M.Bates, "Metallurgical Dictionary", Reinhold, NY (1953), 65 & 250(Centrifugal casting of metals) 5)G.D.Clift, PATR **2381**(1956)(Centrifugal casting of expls for 57mm HEAT shell) 6)A.D. Merriman, "Dictionary of Metallurgy", Macdonald & Evans, London(1958), 33(Centrifugal method of casting) 7)Glossary of Ord (1959), 63(Centrifugal casting) 8)C.W.Briggs, "Steel Casting Handbook", Steel Founders' Society of America, Cleveland, Ohio(1960), 610-11(History of development in US of centrifugal casting process)

**Centrifugal Force of Projectile and Its Utilization for Arming Fuzes and Boosters of Artillery Projectiles.** When a chge of proplnt in an artillery round of ammo is fired in a weapon, the pressure of resulting proplnt gases, causes the projectile to move towards the muzzle. As the pressure of gases increases the speed of proj encreases and this acceleration causes a *setback*. Rifling in the bore of the weapon causes the proj to rotate as it travels towards the muzzle. At the instant the proj leaves the muzzle, it has obtained its max velocity and highest rate of spin. Setback ceases and unattached components develop a tendency to creep forward. To overcome this "creep force" suitable springs are frequently incorporated in a fuze design. Centrifugal force is normally utilized to withdrew a restraining pin or barrier from a component to permit its expl chge to align with the firing pin or another expl chge in the train. Until this has occured the fuze is considered "safe" for handling or shipping. A fuze is considered "armed" (ready to detonate) when all safety devices to prevent arming have been removed and the continuity of expl train has been established

Fuzes and boosters activated by centrifugal force are designed to operate in the rotational velocity range of the missile-weapon

combination in which they are used. Rotational speed is dependent upon the twist of the rifling and the muzzle velocity. For example, the rotational velocity of a 37mm shell fired in the M1A2 gun is ca 66000rpm and of a 105mm shell fired in a howitzer ca 13000rpm(Ref 4,p 245). This means that fuzes for projs fired from these weapons would have different arming characteristics based on the rate of rotation

Fuzes utilizing centrifugal force must be fashioned so that they will not become "unarmed" as the rotational velocity decreases. Some types, also are provided with devices (such as safety wire or cotter pin) to prevent accidental arming during handling or shipping preparations. Such "safety" devices must be removed before firing

In addn to centrifugal force, arming of fuzes can also be accomplished by impact, setback-, setforward- or creep forces and by pressure of gases(Refs 1,2,3,4 & 6)

For testing fuzes contg centrifugal elements, the following "arming test" can be used: The fuze is spun in an apparatus allowed to achieve different speeds of rotation and the lowest speed at which the centrifugal elements move outward is recorded. This insures arming of fuzes at minimum speeds expected in the weapon. Setback elements of fuzes can be tested by dropping them in a "drop-test machine" from a height of drop to simulate the minimum setback in the weapon(Ref 3,p 135) (This section was prepd in collaboration with A.B.Schilling of PicArsn)

*Refs:* 1)Hayes(1938), 580-1 2)Anon, "Ammunition Inspection Guide", TM **9-1904** (1944), 322 3)Ohart(1946), 127-30 & 135 4) Anon, "Artillery Ammunition", TM **9-1901** (1950), 242-5 5)B.A.Gay, "A Study of the Effects of Setback and Centrifugal Force on Non-Solid Shell Fillers", PATR **1785**(1951) (Conf)(Not used as a source of info) 6)Anon, "Ammunition General", TM **9-1900**(1956), 134-9

**Centrifuge and Its Applications.** Centrifuge is an apparatus that subjects a material to a high centrifugal field by very rapid rotation. As the centrifuging field can be varied by changing rotation speeds or dimensions, and as these fields are always much greater than gravity, all operations can be performed more rapidly and in a lesser space by centrifugation than by gravity. In some cases the operations that are not possible by gravity method(as, for example, sepn of gummy or gelatinous solids from liquids) can be carried out by centrifuging

For the sepn of solids from liquids, there are two types of centrifuges: a)Solid wall(such as imperforate basket type) centrifuge, in which sepn or concn is by subsidence or flotation and b)Perforated wall(such as perforated basket type) centrifuge in which the solid phase is supported on a permeable surface thru which the fluid passes. A 3rd type is a combination of a) & b) above. Here the primary concn is achieved by subsidence, followed by drainage of the liquid phase from the solid phase. These centrifuges can be either of batch or continuous operations. For sepn of liquids, there are bottle and tubular centrifuges(Ref 2, 8,10,12,14,16,19,20,21,23,25,26 & 27)

A centrifuge of extremely high speed, which wasdevelopedin 1923 by Svedberg, is known as *ultracentrifuge*. This instrument became very useful in the estimation of particle sizes and in the detn of mol wts of large molecules, such as of cellulose and NC(Refs 3,4,6,7,9,11,17,18,20,22 & 24)

Special laboratory centrifuges used in analysis and research are described in Refs 15,17,20,22, & 24

Centrifuging has been used extensively in chemical industries, including the manuf of expls. For example in the DuPont method of manuf of NC(See this vol of Encyclopedia, under Cellulose, Nitro; Manufacture), the sepn of NC from the spent nitrating acid is done by centrifuging. Another example is the sepn of TNT crysts from "sellite" soln($Na_2SO_3$ in water) and then from wash water, which will be described under Toluene, Trinitro; Manufacture. It can be done by centrifugation or by vacuum filtration using a "Nutsch"

Various centrifuges used in the manuf of NC and expls are described in Ref 1

Walkup(Ref 13) patented in 1949 a basket type centrifuge in which the slurry of explosive particles is fed continuously into a rapidly rotating cylindrical container with perforated walls. The explosive, as it looses the slurry liquid thru the perforations, first forms a lining of conoidal surface and then, subsequently fed particles climb along this surface and are propelled outwardly from the mouth of the container over the edge of the

lining

*Refs:* 1)O.Gründlich, SS **5**, 352-7, 413-18, 434-8, 458-61 & 478-8(1910) & CA **5**, 1841(1911) (Construction & operation of various centrifuges used in manuf of NC & expls) 2)Ullmann **10** (1932), 577-87(Zentrifugen) 3)T.Svedberg, IEC, AnalEd **10**, 113-28(1938)(Ultracentrifuge and its field of research) 4)T.Svedberg & K.O. Pedersen, "The Ultracentrifuge", Clarendon Press, Oxford(1940) 4a)D.R.Cameron, PATR **1062**(1940)(Removal of surface moisture from proplnts by centrifuge) 5)H.Banning, USP 2353983(1944) & CA **38**, 6095(1944)(Description of centrifugal separator for purification of cellulose) 6)N.Gralén, "Sedimentation and Diffusion Measurements on Cellulose and Cellulose Derivatives", Dissertation, Uppsala, Sweden(1944) 7)I.Julander, "Studies of Nitrocellulose", Dissertation, Uppsala(1945) 8)J.O. Maloney, IEC **38**, 24-5(1946) and succeeding years up to 1956, (Centrifugation, under Unit Operations) 9)T.Svedberg, JPhysCollChem **51**, 1-18(1947)(Physico-chem studies of cellulose molecule by ultracentrifugal sedimentation) 10)P.G.Romankov, KhimProm **1947**, No 1, 16-19 & CA **50**, 15139(1956)(A review of info on the newer design of filters & centrifuges for continuous sepn of hard to filter sediments) 11)I.Julander, JPolymerSci **2**, 329-45(1947) (Ultracentrifugal investigations of cellulose & its derivs) 12)Kirk & Othmer **3**(1949), 501-21 (Centrifuges and centrifugal sepn) 13)L.E. Walkup, USP 2490108(1949) & CA **44**, 1709-10 (1950)(Basket-type centrifuge for expls industry) 14)Perry(1950), 992-1013(Centrifuges) 15)S.Oka & G.Muto, JapanAnalyst **1**, 136-40 (1952) & CA **47**, 4781(1953)(Rapid analysis by centrifugal method) 16)Riegel, ChemMach (1953), 367-89(Centrifugals) 17)J.Reilly & W.N.Rae, "Physico-Chemical Methods", Van Nostrand, NY, vol 2(1954), 215-19(Centrifugal action) & 220-25(Ultracentrifuge) 18)J.W. Williams, JPolymer Sci **12**, 351-78(1954)(Sedimentation analysis by ultracentrifuge) 19)J.E. Flood, ChemEngrg **62**, No6, 217-27(1955) (Centrifugals for sepn of solids from liquids) 20)A.Weissberger, Edit, "Physical Methods of Organic Chemistry", Interscience, NY;Vol 1, Part 1(1956), 542-8, 563-606, 655 & 718-23 (Centrifuges and centrifuge filtration & ultrafiltration); Ibid, Vol 1, Pt 1(1959), 224-7 (Centrifugal sedimentation), 226-7(Ultracentrifuges) & 348-9(Centrifugal filtration); Ibid, Vol 1, Pt 2(1960), 1011-39(Centrifugal analysis), 1039-69(Various types of ultracentrifuges) & 1069-96(Methods of measurements by ultracentrifuges) 21)I.M.Abramovich et al, RusP 103110 (1956) & CA **50**, 16204(1956)(A continuously operating centrifuge provided with an automatic discharge of udersized material from the bottom) 22)E.Wiedemann, Dechema Monograph **26**, 330-60 (1956) & CA **51**, 3196(1957)(Development & application of a new ultracentrifuge and some new types of lab centrifuges) 23)I.E.Broadwell, Chem & ProcessEngrg **38**, 432-6(1957) & **40**, 86-90(1959)(Centrifuging; a review) 24)E. Wiedemann, Helv **40**, 1831-4(1957) & CA **52**, 2466(1958)(Lab centrifuges & ultracentrifuges) 25)J.E.Flood Jr., IEC **50**, 428-9(1958) & **51**, 344-5(1959)(Centrifugation; reviews under "Unit Operations") 26)W.Budeberg, Chem-Tech(Berlin) **10**, 341-5(1958) & CA **54**, 16043 (1960)(A review of various industrial centrifgues) 27)J.W.Loy, USP 2921969(1960) & CA **54**, 7257(1960)(Centrifugal crystal purifier)

**Centrifuge Test for Exudation.** It is one the tests used to determine the amt of liquid ingredients(such as NG, NGu, etc) of dynamites and to separate them from solid ingredients (such as AN, sawdust, etc). This test can also be used to det exudation in commercial TNT's. Here "exudate" consists usually of an eutectic mixt of DNT with isomers of TNT, mainly beta and gamma

Centrifuge test is considered to give truer values for exudation than other tests [See Ref 3,p XI, under Exudation(or Sweating) Tests] particularly the Pressure Test(See Ref 1,p 421). This is because in the Pressure Test, the sample of dynamite is subjected to pressure of 80psi and as this pressure is much greater than any that will occur in practice, it may be considered unrealistic. In employing the centrifuge test, the pressure upon any part of the expl is very moderate but is sufficient to remove any liquid film of too great a thickness that covers the particles of absorbent and which might cause the exudation

The procedure for centrifugal testing of dynamites, as was used in England, is described in Ref 1,pp 421-2

This test was also adopted and modified by the USBurMines and is described in Ref 2, pp 25-6). The apparatus consists of two tared perforated porcelain Gooch crucibles, each attached above a solid crucible and each ensemble secured by means of a holder to each

end of the arm of the lab centrifuge. After placing in each Gooch crucible an 8g sample, the radius of rotation of bottom of each outermost crucible is adjusted to 7cm and the temp in the room to 20°. The centrifuge is rotated by hand for 5mins at the rate of 600rpm. The Gooch crucibles are then removed, wiped on the outside and weighed. If the loss in wt of sample is greater than 5%, the expl has failed to pass the test

Gelatinous expls(such as blasting gelatin and gelatin dynamites), or plastic expls (such as PETN or RDX with ca 10% of oil) do not respond to centrifuge test although they sometimes exude in storage. For testing exudation of these expls, the so-called "British Test", described in Ref 2,pp 26-7, can be used

*Refs:* 1)Marshall **2**(1917), 421-2 2)C.E.Munroe & J.E.Tiffany,"Physical Testing of Explosives", USBurMines Bull **346**(1931), 25-6 3)PATR **2700**, Vol 1(1960),p XI

**Cereal Dust Explosions.** See Dust Explosions

**Cereal Meal.** The coarsely ground and unbolted grain of cereals, such as rye, corn, wheat, barley, oats, etc(Ref 2). Some cereal meals have been used as fuel and sensitizer components of industrial expls. Eg: a)French AN dynamite -AN 45, NG 40, Na nitrate 5 & cereal meal 10% (Ref 1,p 341) b)Ger AN expl-AN 61.0, Na nitrate 3.0, cereal meal 7.5, glycerin 3.0, MNT 1.0, NG 4.0 & K or Na chloride 20.5%(Ref 1,p 352) c)Ger Carbonit II-NG 25.0, K nitrate 34.0, Ba nitrate 1.0, cereal meal 38.5, spent tan bark meal 1.0 & Na carbonate 0.5%(Ref 1,p 353) d)Ger Carbonit IV-NG 30.0, Na nitrate 24.5, cereal meal 40.5 & K dichromate 5.0%(Ref 1,p 353)

*Refs:* 1)Davis(1943), 336,341,352 & 353 2) Kirk & Othmer **3**(1949), 634-47

**Cereal Screenings.** Refuse after screening of cereals, which may include bran, small imperfect grains, weed seeds, etc, was proposed for use as a component of some detonating expls, such as those based on NS (Nitrostarch). Eg: a)NS 30-45, TNT 2-10, AN 10-30, Ba nitrate(which in part may be substituted by Na nitrate) 45 & sulfur 0-10 parts are mixed with "cereal screenings" 2-3 & Ca carbonate 0-0.5pts(Ref 1) b)NS 26-30, "cereal screenings 5-8 & sulfur 0-5pts are mixed with Na nitrate 58-65, paraffin oil 0.4-0.5 & Ca carbonate 0-1.5pts(Ref 2)

*Refs:* 1)J.B.Bronstein & C.E.Waller, USP 1188244(1916) & CA **10**, 2150(1916) 2)Ibid USP 1188245(1916) & CA **10**, 2150(1916)

**Cerenkov Radiation.** See Cherenkov Radiation

**Ceresine or Mineral Wax.** See under WAXES

**Ceric-Ammonium Nitrate or Cerium-Ammonium Nitrate.** See under Nitrates

**Ceric-Ammonium Sulfate or Cerium-Ammonium Sulfate.** See under Sulfates

**Ceric Oxide or Cerium Dioxide.** See under Oxides

**Ceric Sulfate or Cerium Sulfate.** See under Sulfates

**Cerium**, Ce at wt 140.13,at No 58; one of the "rare earth" elements; gray, ductile, maleable metal which tarnishes in moist air; d 6.78; mp 645°, bp 1400°; sol in dil acids; insol in cold w & slowly oxidizes in hot w; forms numerous alloys & salts. It occurs in monazite sand which is an orthophosphate of thorium and rare earths. Ce-Fe pyrophoric alloys are used as sparking flints for lighters, tracer bullets & for military signalling. Ce metal is used as component of some rocket propInts and in alloys for jet engines. Toxicity, fire & expln hazards of Ce are discussed in Ref 5. Ce alloy, called *Misch Metal:* Ce 52, Nd 18, Pr 5, Sm 1 & other substances(such as La, Ca, Al, C, Si & Fe) 24%, has many applications. Mixt of Ce & Th oxides is used in Welsbach incandescent gas mantles

Lindeman & Hafstadt(Ref 2) patented detonating expls contg finely pulverized alloy of Ce with Mg or Al with oxidizing agents, such as K chlorate, AN, K permanganate or K dichromate

*Refs:* 1)Mellor **5**(1924), 586-676(Cerium family of rare earths) 2)T.Lindeman & M.Hafstadt, NorwP 44012(1927) & CA **22**, 4251(1928) 3) Thorpe **2**(1938), 507-8 4)Kirk & Othmer **3**(1949), 634-47 5)Sax(1957), 448-9 6)CondChemDict (1961), 241 & 755-6(Misch Metal)

**Cerium Azide.** See Cerium Triazide under Azides, Vol 1,p A528-R of this Encyclopedia

**Cerium Compounds for Smoke Production.** A number of Ce compds contg mixts were proposed by J.DeMent, USP 2995526(1961),p 8, as smoke-producing pyrotechnic compns

**Cerium Dioxide.** See Ceric Oxide under Oxides

**Cerium Hydroxydiazide.** See Vol 1,p 528-R of Encyclopedia

**Cerium Nitrate or Cerous Nitrate.** See under Nitrates

**Cerium Nitride.** See under Nitrides

**Cerium Sulfate.** See under Sulfates

**Cerous-Ammonium Nitrate.** See under Nitrates

**Cerous Nitrate.** See under Nitrates

**Cermets**(Ceramels). Ceramic-metal mixts prepd by powder metallurgy techniques in which a powdered mixt of refractory material(such as metal silicates, oxides or carbides) is molded to the desired form with a metal or an alloy (such as of Co, Ni, Fe, Al, Cr or Mo) and a brazing agent(such as Nb, Ta, Ti or Zr) and then subjected to high temp and pressure. The resulting items combine favorable props of components(such as strength and resistance to high temp, oxidation & thermal shock) and are suitable for use in gas turbines, nuclear reactor mechanisms and rocket & turbojet engines(Refs 1,3 & 5). Use of cermets in ordnance is discussed in Ref 2
*Refs:* 1)G.C.Deutsch et al, "A Review of the Development of Cermets", Advisory Group for Aeronautical Research and Development, NATO, Paris, Report **185**(1958) 2)J.M.Woulbroun, Ordn **44**, 501-5(1959)(Cermets for Ordnance) 3)J.R. Tinklepaugh & W.B.Crandall, "Cermets", Reinhold, NY(1960) 4)CondChemDict(1961), 241-2

**Cesium or Caesium,** Cs, at wt 132.91, silver-white, soft ductile metal, d 1.90, mp 28°, bp 690°; sol in acids & alc; decomp by w; can be prepd by thermochemical reduction of CsCl with Ca. Toxicity and fire & expln hazards of Cs are discussed by Sax(Ref 5). Liquid Cs has been suggested for ion propulsion systems and plasma for thermoelectric conversion(Ref 6). Muraour & Aunis(Ref 4) have shown that salts of Cs & Rb are as effective flash reducers for colloidal proplns as salts of K. Cs metal and its alloys are used in manuf of vacuum tubes and photoelectric cells(Ref 3)
*Refs:* 1)Mellor **2**(1922), 449,451 & 468 2)Gmelin, Syst Nr **25**(1938) 3)Kirk & Othmer **1**(1947), 453-5 & **3**(1949), 648-51 4)H.Muraour & G.Aunis, MP **35**, 296(1953) & CA **49**, 13651(1955) 5)Sax (1957), 450-2 6)CondChem Dict(1961), 243

**Cesium Acetylide-Acetylene.** See Vol 1,p A72-L of Encyclopedia

**Cesium Azide.** See Vol 1,p A528-R

**Cesium Nitrate.** See under Nitrates

**CesiumNitrites.** See under Nitrites

**Cesium Perchlorate.** See under Perchlorates

**Cesium Periodate.** See under Periodates

**Cesium Permanganate.** See under Permanganates

**Cetane Number or Cetane Rating.** It is a measure of ignition value of a Diesel fuel oil (comparable to the octane number rating for gasoline), expressed as percentage by volume of n-cetane [1-hexadecane, $CH_3.(CH_2)_{14}.CH_3$; col liq, bp 287.5°, obtained from petroleum], which must be mixed with 1-methylnaphthalene in order to obtain the same ignition lag as the oil being tested
*Refs:* 1)CondChemDict(1961), 245 2)Merriam -Webster's(1961), 368

**CG 14.** A pre- WWII Ital smokeless proplnt: NC 60, NG 25, DNT(solid) 10 & Centr 5%
*Ref:* M.Giua & G.Guastalla, Chim & Ind(Paris) **29**, 272(1933)

**CH-6, RDX Composition**(U). See L.D.Hampton, NavOrdRept **6880**(1960)(Conf)

**Chaff, Rope, and Window Countermeasures.** *Chaff* is an electromagnetic wave reflector, consisting of a thin narrow piece of metal, designed to be released into the atmosphere (either by dropping from a plane or shot into the air in projectiles) to act as a counter-measure against enemy radar. A grouping of several pieces is called *chaff set.* A similar device, but longer, is called *rope.* A small

parachute may be attached to each piece to reduce the rate of fall. Another similar device, but sometimes metallized only on one side, is called *window*. Original use of the word "window" appears to have been strictly a matter of code
*Ref:* Glossary of Ord(1959), 63,248 & 319

**Chaff Shell or Window Projectile.** Special projectile contg "chaff", "window" or "rope" which is injected in the air to confuse enemy radar
*Ref:* Glossary of Ord(1959), 319

**Chain(in Demolition).** A number of units of demolition charges cast on a length of detonating cord with a short section of cord between adjacent units
*Ref:* Glossary of Ord(1959), 63

**Chain Rammer.** A power-driven chain-linkage device for loading a projectile into the breech of a large caliber cannon, such as in turrets. The power rammer assembly is attached to the racer immediately in rear of the cannon. This system is used to increase the rapidity of fire, and to insure uniform seating of heavy projs
*Refs:* 1)Hayes(1938), 309-11 2)Glossary of Ord(1959), 63-4

**Chain Reaction.** It is a reaction that once started maintains itself by interaction of starting materials with transistory reactive products, such as molecules, atoms or nuclei, and more of the reactive products being formed as they are consumed. M.Bodenstein of Germany was the first to point out(in 1913), that reactions might proceed by a chain of subsidiary reactions. Since then the subject has developed rapidly and is now a well established branch of reaction kinetics

Since WWII, the term "chain reaction" frequently refers to self-propagating fission of atomic nuclei continued by the further action of one of the fission products. For example, when a U-235 nucleus absorbs a neutron, it splits or fissions releasing a great amt of energy and emitting many neutrons, which may, in turn, be absorbed in other U-235 nuclei to propagate the reaction
(See also Atomic(or Nuclear) Energy, Vol 1 of this Encyclopedia,p A500-A504)
*Refs:* 1)N.N.Semenov, "Chemical Kinetics and Chain Reactions", Clarendon Press, Oxford(1935) 2)C.Dainton "Chain Reactions -An Introduction", Methuen, London(1956) 3)CondChem Dict(1961), 246 4)Merriam-Webster's (1961), 370

**Chakatsuyaku.** Japan for TNT
*Ref:* OpNav **30-3M**(1945), 26

**Chakoor Powder**(1903): K chlorate 70, sugar 28 & wax 2%
*Ref:* Giua, Trattato, **6**(1959), 398

**Chalcone and Derivatives**

*Chalcone*(Benzalacetophenone or Betaphenylacrylophenone), (Chalkon in Ger), $C_6H_5.\overset{\beta}{C}H{:}\overset{\alpha}{C}H.CO.C_6H_5$; mw 208.25; yel crysts, mp 57-8°, bp 345-8°(with sl decompn). Other props & prepn in Ref
*Ref:* Beil **7**, 478,(260) & 423
*Mononitrochalcones,* $C_{15}H_{11}NO_3$; mw 253.25, N 5.53%. Seven isomers: 2-, 3-, 4-, 2'-, 3'-, 4'- and α-Nitrochalcones are listed in Ref
*Ref:* Beil **7**, 482-3, (263) & [482-3]
*Dinitrochalcones,* $C_{15}H_{10}N_2O_5$; mw 298.25, N 9.39%. Five isomers: 2,3'-, 3,2'-, 3,3'-, 4,3'-, 4,β-Dinitrochalcones are described in Ref
*Ref:* Beil **7**, 483 & [429]
**Trinitrochalcones,** $C_{15}H_9N_3O_7$; mw 343.25, N 12.24%. Following isomers are described in the literature: *3,3',5'-Trinitrochalcone or 3,5-Dinitro-ω-(3-nitrobenzal)-acetophenone,* $O_2N.C_6H_4.CH{:}CH.CO.C_6H_3(NO_2)_2$; yel crysts(from AcOH), mp 226°; sol in AcOH, acet & ethyl acetate; insol in alc or ether. Was prepd by treating 3,5-dinitroacetophenone with 3-nitrobenzaldehyde in alcoholic HCl(Refs 1 & 3)
*3,3',α-Trinitrochalcone or 3,ω-Dinitro-ω-(3-nitro-benzylidene)-acetophenone,* $O_2N.C_6H_4.CH{:}C(NO_2).CO.C_6H_4.NO_2$; lt yel crysts(from ethyl acetate), mp 152.5-154°; very sol in boiling AcOH; sol in acet, benz & chlf; diffc col in $CCl_4$; insol in ligroin or water. Was prepd by treating 3,3'-dinitrochalcone with absol nitric acid at 0°, either alone or in presence of AcOH or $Ac_2O$(Refs 2 & 4)
*4,3',α-Trinitrochalcone or 3,ω-Dinitro-ω-(4-nitrobenzylidene)-acetophenone,* $O_2N.C_6H_4.CH{:}C(NO_2).CO.C_6H_4.NO_2$; yel ndls(from et acet), mp 135°; sol in the same solvents as 3,3',α-isomer. Was prepd by nitrating 4,3'-dinitrochalcone with absol nitric acid(Refs 2 & 4)

*Refs:* 1)Beil **7**, 483 2)Beil **7**, [430] 3)L. Berend & F.Heymann, JPraktChem **69**, 470 (1904) 4)J. van der Lee, Rec **47**, 426-9 & 430(1928); CA **23**, 116(1929)
*Tetranitrochalcone*, $C_{15}H_8N_4O_9$; *Pentanitrochalcone*, $C_{15}H_7N_5O_{11}$ and *Hexanitrochalcone*, $C_{15}H_6N_6O_{13}$-not found in Beil and in CA's 1907-1960, incl

**Chaluer de combustion**(Fr). Heat of combustion

**Chaleur de détonation(ou d'explosion)**(Fr). Heat of detonation(or explosion)

**Chaleur de formation**(Fr). Heat of formation

**Chaleur spécifique**(Fr). Specific heat

**Chalk.** A native amorphous calcium carbonate composed of calcareous remains of minute marine organisms. It can be used as antacid or stabilizer in expl and proplnt compns(See Calcium Carbonate, under Carbonates)
*Refs:* 1)Hackh's(1944), 185 2)CondChemDict (1961), 247

**Chalon Apparatus.** A very simple app for detg brisance of expls. It consists of two lead cylinders, 40mm in diam & 30mm high, placed one on top of the other vertically with the lower one resting on a cast iron foundation and the upper one covered with a steel disc, 3mm thick. A chge of expl(40-50g), contained in a zinc can, covered with a lid(contg one central hole thru which is inserted either a Bickford fuse or wires of elec detonator) is placed on top of the disc and is exploded. The compression of upper lead cylinder, caused by expln, is measured and compared with that produced by PA, which serves as a "standard"
*Refs:* 1)P.F.Chalon, "Les Explosifs Modernes", Béranger, Paris(1911), 452-3 2)Pepin Lehalleur (1935), 64

**Chambre à poudre**(Fr). Proplnt chamber of a cannon

**Chamber of a Weapon.** In general, it is the part of a weapon in which the firing charge is placed. In a cannon, the chamber(also called "powder chamber"), is the part of gun barrel betw the obturator or breechblock and the forcing cone. In a weapon with fixed ammunition, it is the space occupied by the cartridge case; and in a revolver, it is a hole in the cylinder for inserting a cartridge(Refs 1,2,3,5 & 6)

In a recoillessrifle, the chamber is considerably larger than the cartridge case; therefore the complete round is suspended in the center of the chamber. Ctge cases in these rounds are perforated in order to allow escape of gas to the sides of the chamber and then to atmosphere thru openings(orifices) at the rear of the chamber in breechblock(Ref 3,pp 167-8)

In rockets, there are two kinds of chambers: the "combustion chamber" and "thrust chamber"(See Ref 4)
*Refs:* 1)Hayes(1938), 162 & 165 2)Anon, "Fundamentals of Small Arms", **TM-9-2205** (1952), 72, 83 & 95 3)Anon, "Principles of Artillery Weapons", **TM 9-3305-1**(1956) 26 & 167-8 4)RocketEncycl(1959), 75-8, 96-7 & 517-24 5)Glossary of Ord(1959), 64 6)Merriam -Webster's(1961), 372

**Chambering** is the phase of small-arms operation that deals with the placing of the round into the chamber
*Ref:* Glossary of Ord(1959), 64

**Chamber Pressure.** When a chge of proplnt is ignited within a gun chamber, it burns giving off gases which develop pressure, serving to drive the projectile towards the muzzle. This pressure increases gradually until it reaches a certain maximum, called "peak pressure". After this the pressure decreases until the proj emerges from the gun and then it drops quickly to atmospheric. Peak pressure can be either calcd or detd experimentally by means of devices known as "copper crusher gage" and "piezoelectric gage". These devices, however, do not record the time necessary to reach the peak, nor the rate of increase and subsquent decrease of pressure during the movement of proj. This info can be obtained by means of devices called "recording pressure gages". In one of them, known as "Bichel Pressure Gage", the pressure acts on a piston which, in turn, causes compression of a spring and, at the same time, traces a mark on a drum which is rotated very rapidly by means of an electric motor. In another device, called " 'Petavel Recording Manometer", the motion of piston (usually very small) is magnified many times by causing it to deflect a small mirror which throws a beam of light onto a sheet of photographic paper wound on a drum which is

rotated rapidly(Refs 1 & 4)

Ohart(Ref 3,pp 4 & 5) lists the following maximum chamber pressures,in psi for some of the US weapons used during WWII: 75mm gun 3600, 75mm howitzer 29000, 60mm smooth-bore trench mortar 6000, 81mm smooth-bore trench mortar 6000 and 4.2-in rifled-bore chemical mortar 9000. Ohart also gives(Ref 3,p 88, Fig 39) typical pressure and velocity curves for artillery projs obtained at the Ballistics Research Laboratory, Aberdeen Proving Ground, Maryland

In rockets, the chamber pressure is the pressure developed as a result of burning of solid or liquid proplnts in the combustion chamber. It is usually measured thru the injector face or near the injector end of the thrust chamber by providing a small passage for the gas to press against some external measuring device(Ref 5)

*Refs:* 1)Marshall **2**(1917), 444-53 2)Hayes (1938), 57,65,72,77 & 92-6 2a)Anon, "Ammunition Inspection Guide", **TM 9-1904**(1944), 322 3)Ohart(1946), 4, 5 & 88 4)Glossary of Ord (1959), 219-20 5)Rocket Encycl(1959), 77-8

**Champion Powder.** A blasting, low-grade NG expl developed in the late eighties by the California Powder Works, San Lorenzo, Calif to compete with "Judson Powder", also called "RRP"(Railroad Powder). Both Champion and Railroad powders were similar in compn and were used mostly for bank blasting in RR construction. The exact compn of Champion Powder is not given in the Ref, but RRP was prepd by melting together(with constant stirring) 15parts of sulfur, 3ps rosin, 2ps asphalt, 70ps of Chile saltpeter & 10ps of powdered anthracite coal. The hot mixt was poured on the floor and granulated by raking until cold. The resulting solid grains were coated with 5% NG. RRP and Champion Powder produced on expln a "heaving" rather than "shattering" effect

*Ref:* Van Gelder & Schlatter(1927), 338 & 507-8

**Chanõyaku.** A Japan expl contg TNT 70 & DNN (dinitronaphthalene), 30% used during WWII as a bursting chge for artillery shells

*Refs:* 1)OpNav **30-3M**(1945), 26 2)Antonelli (1960),29

**Chandelon Explosives**(1888). Mixts of org picrates with oxidizers, such as chlorates and / or nitrates. Eg: a)Blasting expl: MNN picrate 28, AN 45 & K chlorate 27% b)Military expl: DNB picrate 57, AN 17 & K chlorate 26% c)Military expl: MNN picrate 33 & K chlorate 67%

*Ref:* Colver(1919), 695-6

**Channel Black.** A variety of carbon black(qv) made by impingement of a luminous natural-gas flame against and iron plate from which it is scraped at frequent intervals

*Ref:* CondChemDict(1961), 248

**Channel(or Canal) Inclusion Compounds.** See under Clathrates and Other Inclusion Compounds

**Chaõyaku.** A Japan expl contg PA 75 & TNT 25%, used during WWII as a bursting chge for aerial bombs

*Refs:* 1)OpNav **30-3M**(1945),26 2)Antonelli (1960), 29-30

**Chapman Explosive,** patented in England 1888, was proposed to replace MF in primers. Its compn was: K nitrate 51.9, P(amorphous) 15.9, K chlorate 10.9, Mg(powder) 6.1, Mn dioxide 5.2, HgO 4.0, K carbonate 2.0, sugar 2.0 & rosin(powder) 2.0%

*Ref:* Daniel(1902), 127

**Chapman-Jouguet Theory.** See under Detonation, Theories of

**Char de Combat**(Fr). Tank

**Characteristic Data(Safety) for Explosive Materials.** Under the title "Sicherheitstechnische Kenndaten explosivfähiger Stoffe", H.Koenen, K.H.Ide et al, describe in Explosivst **1961**, 4-13, 30-42 & 195-7 detns of the following characteristics: density(Dichte), heat of formation(Bildungswärme), heat of explosion (Explosionswärme), temperature of explosion (Explosionstemperatur), ignition temperature (Entzündungstemperatur), chemical stability at 75°(Chemische Stabilität bei 75°), ignitability (Entzündlichkeit), duration of burning (Brenndauer), heating under confinement (Erhitzen unter Einschluss), friction sensitiveness(Reibempfindlichkeit), impact sensitiveness (Schlagempfindlichkeit), expansion in lead block(Ausbachung im Bleiblock,) and sensitiveness to detonation-shock(Sensibilität gegen

Detonationsstoss)

Twenty expl substances were examined and values of their characteristics are given in table,pp 196-7

**Characteristic Product of Berthelot**(Produit caractéristique de Berthelot, in Fr). See Berthelot Characteristic Product

**Characteristics of Explosives and Propellants** (Caractéristiques des Explosifs et des Poudres, in Fr). In France, the following properties are considered "caractéristiques": heat of formation(chaleur de formation); heat of explosion(chaleurde l'explosion); specific volume(volume spécifique)(vol of gas in liters liberated by 1kg of the expl, calcd to 0° & 760mm with w as vapor); temperature of explosion(température de l'explosion)(absol temp reached by gases on expln); covolume (See Ref 2,pp 67-70); pressure of explosion in closed vessel)(préssion de l'explosion en vas clos); velocity of detonation(vitesse de détonation); work performed by the explosive or potential of the explosive)(travail fourni par l'explosif ou potentiel de l'explosif); impact sensitiviness)(sentibilité au choc de mouton); force of explosive(f)(force de l'explosif)(See Ref 2,pp 70-1); brisance by crusher test (brisance par écrasement de crusher); brisance by Kast's formula(brisance d'apres Kast); power by lead block test(CUP par essai au bloc de plomb)(See Ref 6,p XXV, under Trauzl Test); and constants of Muraour $K_1$ & $K_2$(constantes de la vivacité de Muraour $K_1$ et $K_2$(relative quickness of proplnts)(See Ref 2,pp 90-2)

Tavernier detd the following characteristics of some French proplnts: calorimetric potential (potentiel calométrique)(Refs 3 & 4), volume of gases(volume des gaz)(Ref 3) and temperature of explosion(température d'explosion(Ref 4). He also detd the influence of some inorganic additives on characteristics of proplnts(Ref 5)
*Refs:* 1)Pepin Lehalleur(1935), 48, 84 & 94) 2)H.Muraour, "Poudres et Explosifs", Presses Universitaires, Paris(1947), 60-92 3)P. Tavernier MP **35**, 233-72(1953) 4)Ibid **37**, 225-68(1955) 5)Ibid **38**, 267-99(1956) 6)B. Fedoroff et al, PATR **2700**, Vol 1(1960),pp VII,IX,X,XV,XVI,XVII,XX,XXI, & XXVI

**Charbon**(Fr). Charcoal

**Charbonneaux Explosives:** a)Industrial expl: K chlorate 75 & saccharine 25%(Refs 1 & 2) and b)An expl proposed as a bursting charge in shells: Na nitrate 58.8, PA 23.5, MNN 11.8 & Pb dioxide 5.9%(Ref 3). Nitrated petroleum or nitrated turpentine may be substitued for MNN to form a proplnt for rifles
*Refs:* 1)A.E.Charbonneux, USP 886038(1907) & CA **2**, 2622(1908) 2)Escales, Chloratspr (1910), 102 3)A.E.Charbonneux, USP 1174546 (1916) & CA **10**, 1435(1916)

**Charbonnier, P**(1862-1936). Fr general of Naval artillery, specializing in ballistics. Author of several papers and books on ballistics, including "Traité de Balistique Extérieure", Gauthier-Villars, Paris, vol 1 (1921) & vol 2(1927)
*Ref:* Anon, MAF **15**, p VII of 2nd fascicule and pp II-X of 3rd fascicule(1936)(Obituary and brief biography)

**Charbonnier's Contributions in Ballistics.** A complete list of his publications is given in Ref 2 including his important contributions in "Interior Ballistics", and in Ref 3 in "Exterior Ballistics",
*Refs:* 1)Anon, MAF **15**, pp IX-XIII of 3rd fascicule(1936) 2)M.E.Serebriakov, "Interior Ballistics", Oboronizdat, Moscow(1949), translated by Dr. V.Nekrassoff for Aberdeen Proving Ground, Md,p 33 3)M.Garnier, "La Balistique Extérieure Moderne en France", published in MAF **28**, 117-34(1954); pp 131-5 (Method of Charbonnier for calcn of trajectories)

**Charcoal.** A black amorphous substance; a form of carbon derived from the incomplete combustion of animal or vegetable matter (Ref 2). When a pure form of charcoal is desired, it is derived from sugar. Its method of prepn by calcination of sugar heated to ca 800° is described in Ref 3. This method is considered superior to the treatment of sugar with concd $H_2SO_4$. Toxicity, fire & expl hazards of charcoal are discussed in Ref.4

Charcoal is used in various chem processes, as a decolorizing & filtering medium, as absorbent, in pharmaceutical prepns & plastics and as a component of propellants, BkPdr, pyrotechnics & of other expls(Refs 1 & 5). Charcoals used by the US Armed Forces must comply with the applicable specifications (Ref 6)

Marshall, Dict(1920),pp 108-9 lists 33 expls in which charcoal is used as one of the ingredients

*Refs:* 1)Davis(1943), 28,39,42,48,49,52,66,72, 76,79,83-9,92-3,95,99,105,117, 2)Hackh's (1944), 186 3)InorgSynth 2(1946), 74-5 4)Sax (1957), 455-6 5)CondChemDict(1961), 248 6)US Specifications: JAN-C-178A(1)(Charcoal for use in ammunition); LLL-C-251(Charcoal); MIL-C-17605A(Charcoal, activated, technical, unimpregnated); MIL-C-13724A (Charcoal, activated, impregnated, ASC); and MIL-C -10202A (Charcoal, activated, technical) (See also under BLACK POWDER & under Carbon)

**Charcoal, Analytical Procedures.** Analysis of wood charcoal, covering moisture, volatile matter and ash is given in ASTMStds(1961), Part 6, Method **D1762-60T**,pp 860-2

**Charcoal, Brown.** See Brown Charcoal and also Davis(1943), 42

**CHARGE.** An **explosive charge** is a given quantity of expl, contained in a bomb, shell, rocket warhead, torpedo, mine, grenade, fuze, demolition or pyrotechnic item. If the chge, also called *filler*, is used for breaking the casing of a bomb, shell, etc to produce fragmentation or demolition, it is called *bursting (or main) charge*. If the chge is without casing, such as used in detg blast characteristics, it is called *bare charge* and if the chge is within a container, it is called *cased charge* or *confined charge*(if the container is resistant). A small chge of BkPdr or other low expl contained in a "base ejection projectile" for the purpose of expelling the contents, such as smoke canisters, is called *base ejecting charge* or *expelling charge*. A chge used in demolition items is called *demolition charge* and that used for producing craters in earth is known as *cratering charge*. An expl chge used in bombs designed to be dropped or catapulted from a watercraft for use against submarines, etc is called *depth bomb charge*. A chge with a shaped cavity is called *shaped charge*(US), *cavity charge* or *hollow charge*(GtBritain). If the cavity of a shaped charge is lined with sheet-metal, it is called *lined charge* or *lined shaped charge*. This term should not be confused with the *line charge*, which consists of a chain of several split elongated demolition blocks assembled around detonating cord and dropped with attached parachute to keep the chain elongated. Another "line charge", known as *cutting charge* is in the shape of a trough and contains a wedge shaped or curved liner. When detonated on a thick sheet of metal it produces a straight cut (shearing). A similar charge also used for cutting is called *wedge charge*. It is provided with a wedge-shaped cavity, lined or unlined. A demolition expl of great length is known as *linear charge*

The so-called *spotting charge*, consists of a small amt of BkPdr in a practice(or occasionally in service) bomb, shell or mine to show(by producing some smoke) the location of its point of functioning. An expl chge covered with an adhesive substance to make it stick against an object when thrown or planted, is known as *sticky charge*, also called "sticky grenade". An expl consisting of a number of demolition blocks(total wt ca 15lbs), tied together, capped, fuzed and mounted on the end of a pole is called *pole charge*. An expl chge contained in a booster(qv) is called *booster charge* and in a detonator(qv) is *detonator charge*. In a shell provided with a deep cavity(which is intended to seat a proximity fuze, and other type of a fuze can be used provided part of the cavity would be filled with a small removable chge, known as *supplementary charge*

The so-called *springing charge* intended for use with the blast-driven earth rod, M13, as an expl chge which may be inserted into the borehole after the rod has been extracted, is covered by US Spec MIL-C-13882(Ref 7). The chge consists of pellets of Comp B

A **propellent charge**(or *powder charge*) is a given quantity of a "low explosive"(such as BkPdr, colloidal smokeless propInt, composite propInt or liquid rocket propInt), which burns under partial confinement in the bore of a firearm or in a rocket motor in order to propel, by the pressure of resulting gases, a projectile. If a round of ammo in an artillery weapon is "fixed", the propInt chge inside a cartridge is rigidly fixed to the projectile; if it is a "semifixed" ammo, the propInt is in several bags which are, in turn, contained in a cartridge case which is loosely attached to the proj; if it is a "separate-loaded" ammo, the propInt is contained in separate bags which are loaded directly behind a proj in a breech.

A chge consisting of several bags, equal or unequal in size, so that range & muzzle velocity adjustments can be made by increasing or reducing the number of bags( as contrasted with a *single-section charge*, in which the chge cannot be changed) is called *multisection charge*. The bag nearest to the breech is called *base charge* and if it produces a normal velocity of proj, it is also known as *normal charge*. The other section(bags), which are intended to increase the muzzle velocity and range are called *increment charges*. If a multisection chge is made up of equal wt bags, it is called *equal section charge* and if the wts are unequal *-unequal section charge*. A charge intended to produce full service muzzle velocity is called *full charge*, while the chge producing very high muzzle velocity is known as *special charge*. A chge intended to produce muzzle vel below normal is called *reduced charge* and when such chge is used for target practice it is known as *target charge*

In certain cases, such as in some US howitzers, two types of chges are provided, one for inner, the other for outer zones of fire. The cloth of the bags for the inner zone is dyed green, while that for the other zone white. Accordingly there are *green bag charge* and *white bag charge*

A chge of proplnt which travels along the bore with the proj as burning proceeds is called *travelling charge* or *Langweiler charge*. For certain large chges, where the individual proplnt grains are large and it is desired to make the chge as small as possible, the grains are placed end to end within the proplnt bag. This is known as *stacked charge*

*Refs:* 1)Anon, "Ammunition Inspection Guide", **TM 9-1904**(1944), 100,102,104,107,109,115 & 122 2)Ohart(1946),19,36,123,171-2,188-9,192,218, 236 & 239 3)Anon, "Artillery Ammunition", **TM 9-1901**(1950), 4-9,14-17,35 & 333-53 4) Anon, "Ammunition General", **TM 9-1900**(1956), 33-60, 128-131,142 & 260-62 5)Glossary of Ord(1959), 64-7 6)US Specification **MIL-C-13882** (Charge, Explosive, Springing for Rod, Earth, Blast Driven, M13)

**Charge-amorce**(Fr). Primer charge

**Charge, Base.** See under CHARGE

**Charge, Base Ejecting.** See under CHARGE

**Charge, Bursting.** See under CHARGE

**Charge, Cased.** See under CHARGE

**Charge, Cavity.** See Shaped Charge

**Charge, Cratering.** See Cratering Charge

**Charge creuse**(Fr). Hollow or shaped charge

**Charge, Cutting.** See under CHARGE

**Charge, Delay.** See Delay Charge

**Charge, Demolition.** See Demolition Charge

**Charge de poudre**(Fr). Propellent charge

**Charge, Depth Bomb.** See under Charge

**Charge, Equal Section.** See under Charge

**Charge, Expelling.** See under Charge

**Charge, Explosive.** See under Charge

**Charge, Flash.** See under Charge

**Charge, Green Bag.** See under Charge

**Charge, Hollow.** Brit for Shaped Charge

**Charge, Increment.** See under Charge

**Charge Limit or Limit Charge**(Charge limite or Charge maximum in Fr; Grenzladung in Ger). When a chge of an expl is fired in a bore-hole of gassy and/or dusty coal mine, the flame produced on expln might ignite the gas(known as "firedamp") and/or coal dust if the temp of flame is above ignition points of gas or dust. This would cause an expln in mines resulting in many deaths and in damage to the mine. Up to the invention of NG expls, BkPdr was used, nearly exclusively, in most of the coal mines. The precautions to prevent expls of firedamp consisted of using a)"safety lamps"(invented in 1816 by Sir Humphry Davy) b)efficient ventillation in work area and c)rather small chges in bore-holes

When BkPdr started to be replaced by NG expls, the number of disastrous expls of firedamp increased and this forced some European countries to inaugurate studies on

causes of firedamp expls. French Govt created in 1877 the Commission de Grisou, but it was not until 1888, that some safety regulations for use of expls in coal mines were adopted by the Commission des Substances Explosives. These rules were based on recommendations of Mallard & collab, published in MP 2, 355-518 (1884-1889), under the title of "L'Emploi des Explosifs en Présence du Grisou"(See also Ref 8,p 229)

One of the findings of Mallard & collab was, that in order to ignite firedamp it is necessary to have the temp of flame produced on expln of chge, considerably above the ignition point of gas. Another finding was that ignition of firedamp does not take place immediately on contact with flame, but there is a "retardation" of as high as 10secs at temp of flame 650° and lower at higher temps(Ref 11,p 438). If during this induction period, the temp of flame is reduced(due to adiabatic expansion) to below the ignition point of firedamp, there is no danger of expln. As the flame produced by a small chge is easier to cool by expansion, than that of larger chges, most European countries and later the US adopted the idea of "limit charge". This may be defined as: "the largest charge at which no explosion takes place on firing 10(or 5) shots into a *gallery* contg firedamp of approximately the same composition as encountered in coal mines"(Refs 1,3,4 & 8)

Investigations conducted in France, Belgium, England and Germany showed that although each expl compn has a different limit charge, it is usually in the range of 200 to 900g. Marshall(Ref 2) and Barnett(Ref 4,pp 132-41) listed compns and props of many safety expls, including their "limit charges".

In about 1890, Fr Govt, on recommendation of Mallard & Le Chatelier, prohibited the use of BkPdr in coal mines(Ref 11,p 403), but permitted the use of some expls, which were designated as "Explosifs de Surete" or "Explosifs Antigrisouteuses". These were subdivided into "Explosifs Couche" and "Explosifs Roche". For the first, the limit chge was established as 500g with maximum temp of flame(calcd) 1500°; while for the second, the chge was 1000g & the temp 1900°(Ref 4,p 122 & Ref 8,p 238)

In Belgium, the safety expls, designated as "Explosifs SGP"(Explosifs Sécurité -Grisou-Poussière), were adopted and their limit chge established as 900g(Ref 8,p 238 & Ref 11,p 418)

In England the safety expls known as "Permitted Explosives" were adopted and their limit chge was fixed as 28oz(793.8g) (Ref 8,pp 239-40)

In Germany the safety expls, designated as "Wetter- or Wettersichere- Sprengstoffe", were adopted and the limit chge was fixed as 450g for gassy coal mines and 600g for dusty coal mines(Ref 8,p 242)

In US, the safety expls, designated as "Permissible Explosives", were adopted and their limit chge was fixed as 24oz(680g), for untamped chges(Ref 3,p 587 & Ref 8,p 239)

The test formerly used at the USBur-Mines for detg limit charge, was conducted by firing unstemmed chges(in original wrappers) in amts increasing by 25g, into a gallery contg air with 4% of natural gas and 20lbs of bituminous coal dust, (100-mesh, fine), until the maximum amt was found of which 10shots could be fired without causing an expln. The temp of gallery atm was 25°(77°F). The gallery consisted of a cylinder 30.48m in length & 1.93m in diam, built of boiler-plate steel in 5 divisions, each consisting of 3 similar sections. One end of the gallery was closed by a concrete block, while the other end was closed with a steel plate having in its center a hole 12" in diam with a ring 10.5" ID which was made to fit snuggly with the surface of the muzzle of the cannon used in shooting into the gallery. The cannon consisted of a steel cylinder 91.4cm long, 61cm OD & 21.1cm ID. The natural gas consisted(approx) of methane 88.0, ethane 10.8 & nitrogen 1.2%. Out of 20lb of coal dust, 18lbs were placed on shelves laterally arranged along the first 20ft of the gallery, while 2lbs were placed near the inlet system(for the gas) in such a manner that all or part of the dust would be suspended in the 1st division of the gallery (Ref 1,pp 88-9; Ref 3,p 587 & Ref 4,p 123) (Not described in Ref 7)

For description of detns of limit charges, as conducted in Belgium, England, France and Germany, see Refs 3, 4 & 8

According to Pelant(Ref 10), the tests conducted in 1930's at Moravská Ostrava, Czekoslovakia with chges of not "safe" expls ranging betw 200 & 500g, showed that ignition of firedamp took place after each firing. Based on these tests, Pelant came to

the conclusion that limit charge is of no significance

Accdg to Ref 12, the older Russian regulations specified that the maximum chge per bore-hole in gassy coal mines should be 800g. Recent investigations have shown, however, that ignition or non-ignition of fire-damp by a "safe" expl depends rather on the conditions at which expln takes place, than on the wt of the chge. In the new Rus regulations the chge per bore-hole is limited not by its wt, but by the depth of the hole. In blasting of gaseous coal, the size of the chge should never be longer than half of the length of the hole and the remainder should be filled with stemming(tamping)
*Refs:* 1)C.Hall, W.O.Snelling & S.P.Howell, "Investigation of Explosives Used in Coal Mines", USBurMines Bull **15**(1912),pp 82-9 2)Marshall **1**(1917), 390-91 & 395-97 3)Marshall **2**(1917), 582-606 4)Barnett(1919), 122-23 & 132-34 5)Naoúm, Expls(1927), 138(Grenzladung) 6)Naoúm, NG(1928), 385 7)C.E.Munroe & J.E. Tiffany, "Physical Testing of Explosives", USBurMines Bull **346**(1931), 49-57(Detn of capacity of expls to ignite flammable & expl atmospheres) 8)Vennin, Burlot & Lecorche (1932), 228-51 9)Marshall **3**(1932), 187 10) V.Pelant, Chim & Ind(Paris), **Special Number**, p 901(1933) 11)Pepin Lehalleur(1935), 407-22 12)A.I.Seleznev, Ugol' **26**, No 5, 29-30(1951) (Engl translation is available in PicArsnLibrary as U39646) 13)Blasters'Hbd(1952), 26-7

**Chargement en comprimé or Chargement par compression**(Fr). See Press-Loading, under Loading of Ammunition

**Chargement en fondu or Chargement par fusion**(Fr). See Cast-Loading, under Loading of Ammunition

**Chargement en nougat or Chargement mixte** (Fr). See Cake-Loading, under Loading of Ammunition

**Chargement des obus**(Fr). Loading of Shells. See under Loading of Ammunition

**Chargement en semoule**(Fr). See Slurry Loading under Loading of Ammunition

**Charge, Multisection.** See under CHARGE

**Charge, Normal.** See under CHARGE

**Charge, Pole.** See under CHARGE

**Charge, Propellent.** See under CHARGE

**Charge, Propelling, Earth Rod.** A chge of propInt in a metal can used to drive a metal rod into earth or shale
*Ref:* Glossary of Ord(1959), 65

**Charge, Reduced.** See under CHARGE

**Charge Section.** One of the component parts of a chge that is made up of two or more separate parts
*Ref:* Glossary of Ord(1959), 66

**Charge, Shaped.** See Shaped Charge

**Charge, Single Section.** See under CHARGE

**Charge, Special.** See under CHARGE

**Charge, Spotting.** See under CHARGE

**Charge, Springing.** See under CHARGE

**Charge, Stacked.** See under CHARGE

**Charge, Sticky.** See under CHARGE

**Charge, Supplementary.** See under CHARGE

**Charge, Target.** See under CHARGE

**Charge, Travelling.** See under CHARGE

**Charge, Unequal Section.** See under CHARGE

**Charge, Wedge.** See under CHARGE

**Charge Weight Ratio.** The ratio of the wt of a chge(especially an expl chge), to the total weight of the loaded bomb, shell, etc that contains the chge. For example this ratio is ca 50% for GP(general purpose) bomb, ca 70% for LC(light case) bomb, ca 15% for AP(armor -piercing) bomb and ca 30% for SAP(semi-armor -piercing) bomb
*Refs:* 1)Glossary of Ord(1959), 67 2)Encyclo-pedia, Vol 2(1962), under BOMBS

**Charge, White Bag.** See under CHARGE

**Charlotte Ordnance Missile Plant.** A missile assembly plant, located at Charlotte, North Carolina
*Ref:* Glossary of Ord(1959), 67

**Charpy and Izod Tests.** These tests, known also as "notched beam(or bar) impact tests", have been widely used in US for testing the strength of metallic and plastic materials (including those used in ammo). In both tests the specimen is struck by a calibrated swinging pendulum of a pendulum machine(such as the Pendulum-Type Impact Machine, which is briefly described in Ref 2,p 60) and the energy absorbed by the fracture is detd. Both tests employ low striking velocities, such as 17.5ft/sec for the Charpy and 11.5 for the Izod test. In the Charpy Test, the notched bar is placed betw two supports(without using clamps), with notch equidistant betw them and is struck by the pendulum on the side opposite the notch; whereas in the Izod Test, the specimen is held in a vise as a cantiliver bar with center line of the notch on a level with the top surface of the clamping device and the specimen is struck by the pendulum on the notched side 22mm above the edge of the clamp(Ref 2)(See also Ref 4). The testing procedures are given in Ref 3

Gibson(Ref 1) investigated both methods for testing steels, such as used in manuf of shells & gun barrels and gave preference to Charpy Test
*Refs:* 1)W.A.Gibson, PATR **238**(1932) 1a) Hayes(1938), 138 2)M.Hetényi, "Handbook of Experimental Stress Analysis", Wiley, NY(1950), 16 & 60-1 3)ASTM Stds(1961), Pt 3: **A327-54**,pp 75-8 & **E23-60**,pp 79-93 4)W. Späth, "Impact Testing of Materials", Gordon & Breach, NY(1961), 79-85; translation and revision by M.E.Rosner of "Der Schlagversuch in der Werkstoffprüfung", Gentner Verlag, Stuttgart(1957)

**Chassepot Rifle.** A breech-loading rifle invented in 1866 by A.A.Chassepot(1833-1905) and adopted ca 1869 by the Fr forces under the name of "Fusil modèle 1866". It was a bolt-action weapon, which was superior to Ger "needle-gun" invented by N.Dreyse ca 1838. Although "chassepot" had the defect of employing soft paper, self-consuming cartridges, it was used rather successfully during the Franco-Prussian War of 1870-71. The rifle was eventually modified by Capt Gras to adopt a center-fire metallic cartridge, 11mm caliber,and this weapon remained in use until ca 1874, when it was replaced by Gras, 11mm and in 1879 by Gras-Kropatschek, 11mm. All these weapons were single-shot and used BkPdr as propInt
*Refs:* 1)W.W.Greener, "The Gun and Its Development", Cassell, Petter, Galpin & Co, London(1881), 129-31 2)W.H.B.Smith, "Rifles", Vol 2 of the "NRA Book of Small Arms", Military Service Pubg Co, Harrisburg, Pa(1948), 60 & 150 3)Encyclopedia Britannica **5**(1952), 312-13

**Chatellerault Machine Gun**(Fusil-mitrailleur Modèle 1924, in Fr). A weapon also called automatic rifle, adopted in 1924 by the French Army. It used 7.5mm rimless cartridges and its magazine capacity was 30 cartridges. It was manufd at the Chatellerault Arms Plant. Later models(1934-1939) intended for use in tanks, armored cars, airplanes used larger capacity magazines. The so-called "fortress model", used during WWII in Maginot Line had a magazine holding 150 rounds. Chatellerault also furnished an aircraft version which on tests fired 1300 rounds per min
*Refs:* 1)G.M.Chinn, "The Machine Gun", US GovtPtgOff, Washington DC, Vol 1(1951), 401-6 2)M.Lefort, MAF **29**, 800(1955) 3)W.H.B. Smith & J.E.Smith, "Small Arms of the World", Stackpole, Harrisburg, Pa(1960), 139 & 392

**Chatellerault Arms Plant**(Manufacture Nationale d'Armes de Châtellerault). French Govt Arsenal, located at Châtellerault(Vienne), manufg various small arms, including machine guns. It was founded in 1819. A good historic description is given in Ref 2
*Refs:* 1)W.H.B.Smith, "Rifles", Vol 2 of "NRA Book of Small Arms", Military Service PubgCo, Harrisburg, Pa(1949), 150 2)M. Lefort, MAF **29**, 781-800(1955)

**Chauchat Machine Rifle, Model 1915**(Fusil -mitrailleur Chauchat-Suterre, in Fr)(called in England "Chauchard"). A cal 8mm weapon used during WWI by French troops. From Dec 1917 to Apr 1918, nearly 38000 Chauchats were shipped to US to equip nine combat divisions before sailing to Europe. Some of these weapons were altered to caliber .30

*Refs:* 1)G.M.Chinn, "The Machine Gun", US GovtPtgOff, Washington, DC, Vol 1(1951), 238-42 2)W.H.B.Smith & J.E.Smith, "Small Arms of the World", Stackpole, Harrisburg, Pa(1960), 127 & 390

**Chauvet Powders,** patented in 1882: a)K chlorate 95.2 & K ferrocyanide 4.8% and b) K chlorate 90, K ferrocyanide 5 & sugar 5% (Compare with Cauvet & Baron Explosives listed in Vol 2 of this Encyclopedia and with Polveri Baron e Cauvet in Ref p,394)
*Ref:* Giua, Trattato 6(1959), 394

## CHEDDITES OR STREETITES
### (Street Explosives)

(Cheddites, Explosifs Street, Explosifs O or Explosifs du type OC in Fr; Cheddite in Ger; Chedditi in Ital; Chedditas in Span; Sheddity in Rus). Cheddites are special types of chlorate(or perchlorate) explosives. The main feature of Cheddites is that the grains of chlorates(or perchlorates) are coated with liquid(or plastic) materials in order to render the grains less hygroscopic and less sensitive to mech action(such as impact or friction)

*Historical.* Explosives now known as "Cheddites" were invented in 1897 by Street (Ref 1) and in 1898 were patented several varieties of the original compn. One of the formulas contained nitronaphthalene picrate, called in Fr "picronitronaphthalene". At about the same time the Chemische Fabrik Griesheim in Germany patented a similar expl contg nitrotoluene picrate(called in Fr "picronitrotoluene")(See Ref 5,p 740). Manuf of these expls under the name of "Explosifs Street" began ca 1898 by the Société Bergès, Corbin et Cie at Chedde, Haute Savoie, France and certain varieties were admitted to Belgium. They were also exported to England where they were authorized since 1900 under the name of "Cheddites", called so because they were manufd at Chedde. As far as is known, this plant is still in existence(Ref 5,pp 139 & 740-1

A subsidiary of the French firm was established in 1901 in Salviano, near Livorno, Italy(Ref 7). Accdg to Dr Omero Vettori(Ref 35), it is likely that this plant is now one of the plants belonging to the Società Italiana Esplosivo Cheddite with the main office at Torino. This Company which is now a subsidiary of the Société Anonyme Suisse d'Explosifs, Liestal, near Basel, Switzerland has also plants located at Torano(Carrara), Borgofranco(Ivrea) and Cinzano Torinese(Ref 35). Besides France, Italy and Switzerland (Refs 21,27,31 & 35), Cheddites were also manufd in Germany(Refs 21 & 27), Australia (Ref 18), Russia(Ref 20a), Belgian Congo (Ref 28), Algeria(Ref 28), Tunisia(Ref 28) and Finland(Refs 33 & 35). Accdg to Médard(Ref 28), the name of the firm manufg Cheddites in France is the Société Générale d'Explosifs "Cheddite", main office in Paris and the plant at Lamarche-sur-Saône(Côte d'Or). This Company owns also the plant in Algeria(at Bellefontaine) and in Tunisia(Mancuba). Cheddites were alsomanufd inSpain(Ref 26,p 349)

*Chlorate Cheddites* may be subdivided into nongelatin- and gelatin- types. The *non-gelatin-type* Cheddites are in the form of soft grains, white or yellow in color, unless they have been artifically colored by some oil-sol dyes in order to distinguish one type from another. They are readily compressible and in order to obtain the full expl power their density should be carefully controlled. If the d is low the max power is not developed, whereas very high compressions lead to difficulty in detonation. These expls are relatively insensitive to shock and friction at RT and burn, when unconfined, more or less rapidly without any tendency to explode, even when fired in large masses. Heating at 120° for an appreciable period causes no decompn, but at 200° the oil in Cheddite decomposes, part of the nitrocompds volatilizes and the whole mass darkens. Heating of Cheddites in small quantities to 250-65° causes deflagration. Densities of compressed materials average 1.3-1.4; power(by Trauzl test) slightly below that of TNT, but their brisance (by Kast's formula or by Cu crusher test) is only 30-50% of TNT, due to the low detonation velocity, 2300-3200m/sec(as detd by the method of Dautriche). This rate depends not only on compn but also on density. It increases with the d up to a certain point(optimum density) and then decreases very rapidly. For example, one of the Cheddites developed the rate 2283m/sec at d 1.07, it increased to 2901 at d 1.17, dropped to 2451 at d 1.14 and failed to detonate at d 1.5(Refs 13,15,20 & 23)

Information in the literature on expl

props of Cheddites is rather scarce, but whatever is available is shown here in Tables or in Notes to Tables

None of the Chlorate Cheddites can contain any Amm salt, because double decompn might take place with the formation of dangerous Amm chlorate. Cheddites contg K or Na perchlorates are more stable and less reactive than those contg K or Na chlorates. Amm perchlorate may also be used, provided chlorates are absent. Na chlorate is more hygroscopic than K chlorate but it is more economical and contains more oxygen per unit wt(Ref 24,p 359)(See Tables 1,2 & 3)

The *gelatin-type* Cheddites are plastic type expls which do not harden in storage. They were developed in 1911 by C.Rubins and manufd by the Cheddit & Dynamit AG, Liestal, Switzerland and then in other countries. These expls are not very powerful, but their brisance is superior to any AN expl. They are very effective for work in galleries, especially with humid and not too hard rocks(Ref 21,p 313; Ref 27,p 90; Ref 30,p 180 & Ref 31,p 118)(See Table 3)

*Manufacture of Cheddites.* For *non-gelatinized* types the following procedure may be used: One or several expl compds [such as MNN, DNN, MNB, MNT, DNT, liq TNT(Drip Oil), PA azo- or azoxybenzene, etc], are dissolved in a heavy oily substance(such as castor-, linseed-, olive-, or pertoleum oil, paraffin, wax, fat, vaselin, pitch, tar, resin or plastic material) by heating the mixt in a steam-jacketed enamelled iron pan at temps of 65-80°. When the mass becomes homogeneous, it is allowed to cool to ca 55°, and then preheated(to ca 50°), dry and finely pulverized chlorate(or perchlorate) is gradually introduced, while stirring with a wooden spatula. As soon as it becomes evident that the particles of powder are uniformly coated with oily mixt, the slurry is transferred to another building where it is poured onto a flat wooden surface and rolled into a thin layer for cooling to 30-35°. Then the resulting solid mass is broken by means of a wooden roller into grains and these are passed thru a screen, to remove the very fine particles. Finally the grained Cheddite is made into cartridges by pressing in wooden molds from which it is transferred to paper cartridges. Cartridges contg Na chlorate Cheddite should be dipped in molten paraffin or wax in order to render them non-hygroscopic(Refs 1,2,3,4,5,7,11,13,14,15, 17,20,20a,23,26 & 30)

Some Cheddites patented by Street(Ref 2), were prepd by coating K chlorate with "sulfurated oil", which was obtained by heating to 180° ca 10ps of sulfur in 90ps of an oil, preferrably linseed oil. Another variety patented by Street(Ref 4) was obtained by incorporating K chlorate with varying relative quantities of a mixt of charcoal and PA with pitch, tar or vegetable oil

For *gelatin-type* Cheddites, the nitro-compds(see under manuf of non-gelatinized types) are mixed with NC & NG and heated to ca 40° until the mass becomes uniform. Then a finely powdered chlorate is added and coating is conducted with stirring, but without raising the temp(Ref 23)

Detailed description of manuf of French Cheddites as it was done at the Poudrerie de Vonges is given in the book of Vennin, Burlot & Lécorché(Ref 20,pp 541-3). A good description of its manuf in Spain is given by Vivas, Feigenspan & Ladreda(Ref 26,pp 350-1)

*Compositions of Cheddites.* Some formulations of Cheddites contg azobenzene are listed in Vol 1,p A647-L of Encyclopedia and some examples of Cheddites contg castor oil are given in Vol 2, under Castor Oil

The first Cheddites or Street Explosives studied and approved for manuf at the Poudrerie de Vonges by the French "Commission des Substances Explosives", beginning 1897, had the compns listed in Table 1(Refs 1a,5,13,15, 20 & 24)

**Table 1**

| Composition | I | II | III |
|---|---|---|---|
| K chlorate | 75.0 | 74.6 | 80 |
| Picronitro-naphthalene | 20 | – | – |
| Nitronaph-thalene | – | 5.5 | 12.0 |
| Starch | – | 14.9 | – |
| Castor oil | 5.0 | 5.0 | 8.0 |
| Sensitivity to shock | Lower than that for No 1 Dynamite (NG 75 & kieselguhr 25%) | | |
| Brisance | | | |
| Rate of detonation | | | |

*Note:* Picronitronaphthalene or Nitronaphthalene Picrate is an equimolecular combination, $C_{10}H_7(NO_2).C_6H_2OH(NO_2)_3$, mp 71° [See Jovinet, MP **23**, 37(1928)]

Prior to WWI and probably up to WWII Cheddites listed here in Table 2 were author-ized in France and large quantities were

exported to Belgium, England and other countries. It is probable that most of these Cheddites were manufd at the time of publication(1932) of the book of Vennin, Burlot & Lécorché(Ref 20)

**Table 2**
**French Chlorate Cheddites or Explosifs O**

| Composition | On°1 41 | On°1 60bis | On°2 60bisM | On°4 | On°5 | On°5 bis | On°6 A | On°6 B | On°6 C | On°7 | On°8 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| K chlorate | 80 | 80 | 79 | 90 | – | – | 90 | 90 | 89 | – | – |
| Na chlorate | – | – | – | – | 79 | 79 | – | – | – | 90 | 90 |
| MNN | 12 | 13 | 1 | – | – | – | – | – | – | – | – |
| DNT(cryst,mp 67-9°) | – | 2 | 15 | – | 16 | 2 | – | – | – | – | – |
| TNT | – | – | – | – | – | 14 | – | – | – | – | – |
| Castor oil | 8 | 5 | 5 | – | 5 | 5 | – | – | – | – | – |
| Paraffin | – | – | – | 10 | – | – | 7 | 7 | 5 | 7 | 10 |
| Vaselin | – | – | – | – | – | – | – | 3 | 4 | 3 | – |
| Heavy petr oil | – | – | – | – | – | – | 3 | – | – | – | – |
| Pitch, tar or rosin | – | – | – | – | – | – | – | – | 2 | – | – |

*Notes to Table 2* are listed below Table 3 and *Notes to Table 3* are on p C 158

**Table 3**
**Various Chlorate Cheddites(Non-gelatin Types**

| Composition | French Cheddites 41 | 60 | 60N (older) | 60N (newer) | On°5 | On°14 | On°14 A | P | S | British ? | Swiss ? | German 60N | 2 | 3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| K chlorate | 79 | 80 | – | – | – | – | – | 90 | – | – | 73 | – | 80 | 90 |
| Na chlorate | – | – | 80 | 75 | 77 | 87.7 | 87.5 | – | 89 | 79 | – | 79 | – | – |
| MNN | 15 | 12 | 13 | 19 | – | – | – | – | – | – | – | – | – | – |
| DNT | – | – | 2 (cryst) | 1 (cryst) | 2.3 (liq) | 4.3 (cryst) | 4.5 (liq) | – | – | 16 | 16 | 2 | 10 (liq) | – |
| TNT | – | – | – | – | – | – | – | – | – | – | – | 14 | 5 | – |
| Castor oil | 6 | 6 | 5 | 5 | – | 0.9 | – | – | – | – | 5 | 5 | 4 | – |
| Resinous oil | – | – | – | – | – | – | – | – | – | 5 | – | – | – | – |
| Paraffin | – | – | – | – | – | 7.1 | 8.0 | 10 | 11 | – | – | – | – | – |
| Heavy petr oil | – | – | – | – | – | – | – | – | – | – | – | – | – | 10 |
| PA | – | 2 | – | – | – | – | – | – | – | – | – | – | – | – |
| Starch | – | – | – | – | – | – | – | – | – | – | 6 | – | – | – |
| Sawdust | – | – | – | – | – | – | – | – | – | – | – | – | 1 | – |
| Power(PA = 100%) | | | | | 87 | 80 | 80 | | | | | | | |
| References | 11, p128 21 p314 | 11, p111 | 11, p124 | 11, p128 | 29, p212 | 29, p210 | 29, p212 | 13, p496 24, p361 | 13, p496; 24, p361 | 14, p167 | 14, p168 | 27, p87; 31 p113 | 21, p314 | 21, p314 |

*Notes to Table 2:*

A)Following properties are given for Cheddite **On °2 60bisM**(modifiée) by Sukharevskii & Pershakoff(Ref 20a): density, g/ml 1.4(TNT 1.59), heat of formation+666cal/g(TNT +70.5), heat of explosion 1185cal/g(TNT 950), volume of gases of expln 337 l/kg(TNT 690), ignition (deflagration) temp ca 260°(TNT ca 300°), max temp of expl 4500°(TNT 2280°), detonation rate 3000m/sec(TNT 6700), power by Trauzl test 255cc(TNT 285), brisance by Kast's formula $23.8 \times 10^6$(TNT $86.1 \times 10^5$), brisance by Cu cylinder crusher test 1.4mm(TNT 3.6), sensitiviness to friction by rubbing in porcelain mortar explodes(TNT does not), sensitiviness to impact, using 2kg weight 30cm(TNT 60cm)

B)Médard(Ref 29,p 210) gives power(CUP) for On°5 86% of PA and for On°8 78%

C)Cheddites On °6 were used during WWI for military purposes under the names of *Minélite A, Minélite B and Minélite C*. The best known was

Minélite B which was used for loading grenades and mines. A similar Cheddite contg 90% of Na chlorate instead of 90 of K chlorate was used in grenades and trench mortars(Ref 24,p 361)
D)Accdg to Vennin et al(Ref 20), the most popular type of Cheddite used in France after WWI was On °5 and the next in popularity was On °8
E)Accdg to Giua(Ref 32,p 398), a variety of Cheddite, prepd by coating the grains of K chlorate with a mixt of linseed oil and an amide was patented in 1903 by Brown & Moore for use as a smokeless proplnt

There were many other Cheddites used prior to WWII and several of them are listed in Table 3

*Notes to Table 3:*
A)Cheddite known in France as P was designated in Germany as *Miniersprengstoff*. It was used for demolition work, such as destroying bridges, RR switches etc(Ref 27,p 91)
B)Barnett(Ref 15,p 109-11) gives for Cheddite P detonation velocity 3565m/sec at d 1.45 and for Cheddite S 2940 at d 1.45. He also lists *Cheddite Type 60*[4]: K chlorate 75, MNN 10 & DNT 15% with deton vel 3156m/sec at d 1.48
C)To the list of Brit Cheddites may be added *Colliery Cheddites:* K chlorate 76.5-79.5, MNN 15.5-14.5, DNT 2.5-1.5, castor oil 5.5-4.5 & moisture up to 1%(Ref 14,p 279)
D)Ger Cheddite designated as 2 was used, under the name of *Miedziankit* in Ger-Polish mines(Ref 21,p 314; Ref 27,p 91; Ref 31,p 118)

Accdg to Médard(Ref 29), Cheddites are known now in France as *Explosifs OC* (or Explosifs O) and they are still in demand in mining and quarrying operations. Because chlorates(and perchlorates) require much electric energy for their manuf, the Cheddites are rather expensive and they are gradually being replaced by cheaper nitrate expls(mostly based on AN), known in France as *Explosifs Nitratés or Explosifs N*. In order to make Cheddites less expensive, so that they might compete with Explosifs N, research has been undertaken in France, mostly at the laboratory of CSE(Comission des Substances Explosives). As a result of this research some improved and less expensive formulations were developed. One of the economic improvements was the replacement of crystalline DNT(mp 67-9°) with cheaper, crude(called "liquid") DNT(mp 50-8°)(Compare expls of Table 2 with On °5A and On °14A of Table 3). Use of Na chlorate in lieu of K chlorate also contributed towards reduction of cost, but it also made the Cheddites more hygroscopic. This disadvantage can, however, be overcome by waterproofing the containers(paper cartridges) with molten paraffin. More serious disadvantage of Na chlorate Cheddites is the proximity of "optimum" density(at which the expl performs the best) to "limite density"(densité limite" in Fr) at which the expl becomes insensitive to initiation

Older French Cheddites On °5, On °6B, On °8 & On °14(See Tables 2 & 3) had low "limite" or "optimum" densities, low deton velocity and low power(CUP). As their oxygen balance was positive it was presumed that by bringing it closer to zero,(such as by increasing the amt of DNT), it would be possible to obtain more powerful expls. This, however, did not achieve the purpose, because the addn of extra DNT increased the density of the compn above its "optimum" value and rendered it sometimes insensitive to initiation. In order to avoid this, it was proposed to reduce "d" by incorporating some light materials, such as cork flour or sawdust(see expls 55-CSE-1948 and 58-CSE-1948 in Table 4). These expls were slightly more powerful than older type Na chlorate-DNT Cheddites, but their manuf was more tedious because it had to be conducted in two steps, using two different bldgs in order to avoidexplns due tosimultaneous presence of dusts of a fuel and of an oxidizer in the same bldg. In the 1st bldg liq DNT was mixed with cork flour or sawdust and the paste transferred to the 2nd bldg where powdered Na chlorate was incorporated

The CSE also conducted research on *Gelatin-Cheddites*, which were already known in Switzerland and in Italy(See Swiss & Ital Gelatin-Cheddites in Table 4). A corresponding French formulation, known as On °18 was really no improvement over Swiss & Ital types. It was difficult to detonate unless detonating cord was used. Much more powerful "Gelatin -Cheddites" were obtained when Na chlorate was replaced by Amm perchlorate and when PETN was incorporated(See below under Perchlorate Cheddites)

Accdg to Dr Omero Vettori(Ref 35), the following Cheddites have been manufd by the Società Italiana Esplosivo Cheddite at the Salviano(Livorno) plant: a)*Cheddite OS Extra* b)*Cheddite O Extra* c)*Cheddite O Extra B* d)*Plastigel I* and e)*Plastigel II*(See Table 4). Their compn & props are given by Dr Vettori. Stability of Plastigel is >30mins at 60°

**Table 4**
**Newer Types of Chlorate Cheddites**

| Composition and Some Properties | French 55 -CSE -1948 | French 58 -CSE -1948 | Italian Cheddites OS Extra | Italian Cheddites O Extra | Italian Cheddites O Extra B | Swiss & Ital Gelatin Cheddites Older | Swiss & Ital Gelatin Cheddites Newer | French Gelatin Cheddite n°18 | Italian Plastigels I | Italian Plastigels II |
|---|---|---|---|---|---|---|---|---|---|---|
| Na chlorate | 74 | 74 | 90 | 79.0 | 82.6 | 75 | 70 | 74.0 | 72.0 | 72.0 |
| DNT(liquid) | 23 | 23 | – | 16.0 (liq) | – | 23.8 | 23.5 | 19.0 | 19.7 | 19.7 |
| Sawdust | – | 3 | – | – | – | – | – | – | – | – |
| Cork flour | 3 | – | – | – | – | – | – | – | – | – |
| NG | – | – | – | – | – | – | 5.0 | 5.5 | – | – |
| Collodion cotton | – | – | – | – | – | 1.2 | 1.5 | 1.5 | 1.8 | 1.8 |
| Castor oil | – | – | – | 5.0 | – | – | – | – | – | – |
| Paraffin | – | – | 7 | – | 5.0 | – | – | – | – | – |
| Vaselin | – | – | 3 | – | 2.4 | – | – | – | – | – |
| PETN | – | – | – | – | – | – | – | – | – | 6.5 |
| TNT | – | – | – | – | 10.0 | – | – | – | 6.5 | – |
| Oxygen balance % | – | – | +6.08 | +3.90 | +4.32 | – | – | – | +4.4 | |
| Density, g/cc | – | – | ca 1 | ca 1 | ca 1 | 1.9 | – | 2.0 | ca 2 | |
| Detonation rate, m/s | – | – | 3000 | 3200 | 3200 | – | – | – | 3600 | – |
| Power(PA 100%) | 93 | 89 | 80 | 94 | 85 | 83 | 83 | 83 | 108 | – |
| Impact test, cm, 2kg | – | – | >18 | 28 | >16 | – | – | – | 24 | – |
| References | 29 | 29 | 35 | 35 | 35 | 21 & 30 | 21 | 29 | 35 | 35 |

*Perchlorate Cheddites* are those based on perchlorates, such as of K or Amm. Mixts based on $KClO_4$ are more powerful, more stable and less sensitive to ignition, friction and percussion than corresponding mixts contg $KClO_3$. Mixts contg $NH_4ClO_4$ are even more powerful than those contg $KClO_4$ and they are sufficiently insensitive to be handled with safety. Some Perchlorate Cheddites were used for military purposes

In Table 5 are listed some typical Perchlorate Cheddites. Two French plastic Cheddites, designated as *Sevranite n°1 and Sevranite n°2* were developed at the laboratory of CSE after 1946. They are much more powerful than any previously known Cheddites(CUP is 142% PA for n°1 and 138 for n°2) and their detonation velocity is ca 7000m/sec at d 1.55 (Ref 29,pp 218-19)

**Table 5**
**Perchlorate Cheddites**

| Composition | French I | French II | French III | Brit Blastine | German Military | German Perchloratits 1 | German Perchloratits 3 | German Perchloratits 3 | Swed Territ | French Sevranites no1 | French Sevranites no2 | Belgian Yonckite |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Amm perchlorate | 82 | 50 | 88-90 | 60 | – | – | – | – | 43 | 31 | 42 | 43 |
| K perchlorate | – | – | – | – | 56 | 68 | 35 | 34 | – | – | – | – |
| Amm nitrate | – | – | – | – | – | 10 | 42 | 48 | – | – | – | – |
| Na nitrate | – | 30 | – | 22 | – | – | – | – | 28 | – | – | 32 |
| MNN | – | – | – | – | 12 | 1 | – | – | – | – | – | – |
| DNB | – | – | – | – | 32 | – | – | – | – | – | – | – |
| DNT | 13 | 15 | – | – | – | 16 | 14 | 12 | 27.8 | – | – | – |
| TNT | – | – | – | 11 | – | | | – | | – | – | 15 |
| Castor oil | 5 | 5 | – | – | – | – | – | – | – | – | – | – |
| Paraffin | – | – | 12-10 | 7 | – | – | – | – | – | – | – | – |
| NG | – | – | – | – | – | 4 | 4 | – | – | – | – | – |
| Collodion cotton | – | – | – | – | – | – | – | – | 1.2 | – | – | – |
| Woodmeal | – | – | – | – | – | 1 | 5 | 6 | – | – | – | – |
| PETN | – | – | – | – | – | – | – | – | – | 48 | 42 | – |
| Plasticizer | – | – | – | – | – | – | – | – | – | 18 | 16 | – |
| Al powder | – | – | – | – | – | – | – | – | – | 3 | – | 10 |
| References | 8 | 8 | 21 p316 | 21 p316 | 21 p316 | 21 p316 | 21 p316 | 21 p316 | 21 p316 | 29 pp 218-19 | | 21 p316 |

*Notes to Table 5:*

A)French expls I & II were designed to be used for industrial purposes, while III was used during WWI under the name of *Perammon* for filling bombs

B)Brit *Blastine* was used for blasting operns, including military

C)Ger Military Cheddite was used during WWI for cast-loading land- and sea-mines

D)Ger *Perchloratits* were used for industrial purposes

F)Fr *Sevranites*, use is unknown

G)Belg *Yonckite*(spelled in Ger *Jonckit*) was used for military and industrial purposes

H)Detonation velocity for French I 4020m/sec at d 1.04, and for II 3361m/sec at d 1.04

*Uses of Cheddites.* Although Cheddites were originally designed to be used for industrial purposes, some of them were used during WWI for military purposes, such as demolition work, loading bombs, grenades, mortar shells and land- & sea-mines(See also Notes under Tables 2, 3 & 5)

*Refs:* 1)E.Street, EngP 9970(1897): FrP 267407(1897); JSCI **17**, 375(1898)(Expls obtained by coating the grains of K chlorate with nitrocompds dissolved in oils by heating at 40-60°, with stirring followed by cooling) 1a) CSE(Commission des Substances Explosives), MP **9**, 144(1897-8); **11**, 22(1901) & **12**, 117 & 122(1903-4) 2)E.Street, EnglP 12760(1898) & JSCI **18**, 400(1899)(Expls prepd by coating 13)Marshall **1**(1917), 380-2(Some Cheddites & their manuf and **2**(1917), 496(Some Cheddites & their props) 14)Colver(1918), 167-9, 279-80 & 640(Some Cheddites & expl props); 279(Manuf) 15)Barnett(1919), 109-12(Various Cheddites and props) 16)Marshall, Dict(1920), 21(Two types of Fr Cheddites manufd after WWI) 17)Ullmann **4**(1929), 788, under Explosivstoffe (In new edition it will be listed under Sprengstoffe) 18)R.J.Lewis, "Report of the Chief Inspector of Explosives of Victoria (Australia) for 1929", Melbourne(1930) (Cheddites as authorized expls in Australia) 19)Marshall **3**(1932), 153 & 155(Compn & props of Cheddite 60M) 20)Vennin, Burlot & Lécorché(1932), 539-46(Cheddites, called also Explosifs Street or Explosifs O) 20a) Sukharevskii & Pershakoff(1932), 150 & 198-201 (Manuf & props of Cheddites) 21)Stettbacher (1933), 309-15(French, Swiss & German Cheddites) 22)Pepin Lehalluer(1935), 344-9 (French Cheddites) 23)Thorpe **2**(1938), 525 (Compns, manuf & props of various Cheddites) 24)Davis(1943), 357-60 & 365-6(Various Cheddites) 25)Pérez Ara(1945), 207-8(Cheddites) 26)Vivas, Feigenspan & Ladreda **2**(1946), 349-51(Compn, manuf & props of K chlorate and Amm perchlorate Cheddites) 27)Stettbacher (1948), 87 & 90-1(Compn & some props of Cheddites manufd in Switzerland and Germany) 28)L.Médard, MP **32**, 210-12(1950)(Cheddites grains of K chlorate with "sulfurated oil") 3)E.Street, EnglP 13724(1898) & JSCI **17**, 488 (1898) [Expls prepd by coating the finely pulverized alkaline chlorates or perchlorated (with or w/o addn of carbonates or hydrocarbonates) with and "oily substance prepd by dissolving at 65 to 100° nitrocompds and/or azo-, azoxy-, amidoazo- or amidoazoxybenzene in an oil (such as linseed, olive, petroleum oils)] 4)E.Street, EnglP 24468 (1898) & JSCI **18**, 1051(1899)(An expl consisting of powdered $KClO_3$ coated with pitch, vegetable oil or tar and mixed with powdered charcoal and PA) 5)Daniel(1902), 134 & 740-4(Compns of various Cheddites and their prepn) 6)CSE (Commission des Substances Explosives), MP **13**, 144-8 & 282(1905-6)(Compn & props of Cheddite 60bis & 60bisM)(M stands for "modifiée") 7)E.Bravetta, SS **1**, 125-7(1906)(Manuf of Cheddites 41, 60 & 60bis at Salviano plant in Italy) 8)CSE, MP **14**, 192-5 & 206-33(1906-7) (Cheddites based on Amm perchlorate) 8a) Gody(1907), 267-8 9)H.Dautriche & E.Burkard, SS **4**, 204-7 & 224-8(1909)(Prepn & props of Cheddites listed in Ref 8) 10)CSE, MP **15**, 135-7(1909-10)(Props of Cheddite proposed by Bergès, Corbin & Cie:Na chlorate 75, DNT 19, MNN 1 & castor oil 5%) 11)Escales(1910), 110-142(Chlorate Cheddites) & 163-84(Perchlorate Cheddites) 12)H.Dautriche, MP **16**, 66-8, 211-12 & 224-9(1911-12)(Cheddites with $NaClO_3$)

manufd in France before WWII under the names of *Explosifs du type OC* or *Explosifs chloratées* were of high quality at comparatively low price, especially those contg liq DNT. Médard gives compn of several expls of this type and lists the plants manufg them) 29)L.Médard, MP **32**, 215 & 218-22(1950) [Compns and some props of modified Cheddites developed and tested during 1948-1949 in laboratories of CSE (Commission des Substances Explosives)] 30)Belgrano(1952), 179-81 & 184(Compns, props and methods of manuf of several Ital Cheddites) 31)Stettbacher(1952), 113 & 117-18(Swiss Cheddites manufd by the Cheddite & Dynamit AG at Liestal) 32)M.Giua, "Trattato di Chimica Industriale", UTET, Torino, Vol 6 (1959), 396(Compns, some props of Cheddites, types 41, 60bis & 60bisM; also of two Amm perchlorate Cheddites) 33)I.Huhtanen, Explosivst **1960**, 189-94(Cheddite-type expls used in Finland) 34)K.K.Andreev, Explosivst **1962**, 229(Some props of Cheddite Type 60) 35)Dr Omero Vettori of Società Italiana Esplosivo Cheddite, Via Cernaia 15, Torino, Italy; letters of Nov 24, 1962, Jan 10, 1963, Feb 2, 1963 and March 7, 1963

**Cheddites, Analytical Procedures.**
*Qualitative Tests.* For Cheddites contg a chlorate, binding materials(paraffin, vaselin, castor oil, etc) and powdered coal, a sample (10-15g) is heated for 1hr, under reflux, with ether(or benz), the extract filtered and evapd to dryness. It leaves as deposit the binder. The non-extractable material is treated with hot w to dissolve the chlorate, thus leaving coal as residue. The aq soln is evapd and 0.2-0.3g of solid is heated in a test tube. Evoln of oxygen, manifested by burning with bright flame of a glowing wood splinter inserted into the neck of the test tube, indicates the presence of a chlorate(or perchlorate). The residue after extraction with w is examined for coal by burning a small portion on the tip of a metallic spatula. For Cheddites contg, in lieu of coal, some nitrocompd(such as a nitro-naphthalene, nitrobenzene, nitrotoluene or PA), the residue(binder) after ether(or benz) extraction is tested for chlorate(or perchlorate), as described above, but one-half of the evapd extract is treated in cold with 10% Na or K hydroxide. This dissolves nitrocompds leaving fatty substances as residue. The other half of evapd ether(benz) extract is tested for nitrocompds by various colorimetric procedures. In testing for PA a small part of the residue is treated with w and if the color of liq turns yel, some KCN soln is added. If the color turns purple-red, the presence of PA may be considered as proved. TNT is recognized by a deep purple -red color produced when an alcoholic or acetonic soln of evapd ether(or benz) extract is treated with Na or K hydroxide. Under the same conditions, DNT(if free from TNT) gives a blue color. If TNT is also present the blue color of DNT is masked by purple-red color of TNT. Heating by direct flame of the test tube contg ca 0.5g of residue and 6ml of 25% alc NaOH soln causes, in case of TNT, sym-TNB, or Trinitro-metaxylene(TNX) evoln of ammonia, leaving the soln colored intensively brn-red. Nitronaphthalenes also evolve ammonia, but DNB, 2,6-DNT and MNT do not, while 2,4-DNT does it only after prolonged heating

TNB, TNT and TNX, dissolved in acetone, develop dk-red color on adding a few drops of ammonia. This reaction can also be used to distinguish between $\alpha$, $\beta$ & $\gamma$-TNT's, which give correspondingly dk-red, green and blue colors. If "Drip Oil"(mixt of crude DNT & TNT) is present the color with ammonia is red at the beginning, but, it turns violet on standing. MNB and MNT do not produce any color when treated with a caustic or ammonia, but their presence in Cheddites can be detected by bitter almond odor (Ref 1,pp 137-8)(See also under Quantitative Tests)

When TNT is present in mixt with DNT, it is very difficult to detect DNT by blue color produced on contact with Na or K hydroxide, because the red-violet color produced by TNT is very intense and it masks the blue color of DNT. For rapid colorimetric detection of DNT, in presence of TNT a method developed during WWII at Keystone Ordnance Works, Meadville, Pa is recommended. The procedure is based on the fact that DNT is practically insol in cold concd soln of Na sulfite(known as *sellite*), while TNT is very sol. It is described here because Ref 3, where the method originally appeared, is now out of print *Procedure:* Triturate in a small mortar ca 1g of sample(in which the presence of DNT and/or TNT is suspected) with a few mls of $CCl_4$, allow to settle and decant the extract into a small separatory funnel. As soly of DNT in $CCl_4$ is ca 3.5% and of TNT only 0.74%, this treatment will dissolve the bulk of DNT, leaving a large

proportion of TNT undissolved. Shake the extract in a separatory funnel with an equal vol of 1/% sellite soln slightly acidified with $H_2SO_4$. Allow to settle and remove the bottom layer(soln of DNT in $CCl_4$) to a small beaker. Discard the red upper layer(sellite with the TNT decomposed by treatment) and transfer the $CCl_4$ layer back to the funnel. Repeat once or twice the treatment using fresh portions of sellite and test the $CCl_4$ soln for the presence of DNT. For this, place 2 drops of the soln into the hollow of a porcelain spot plate, add 5 drops of freshly prepd concd KOH soln in 1:1 alc-acet and observe the color. Blue or a blue with a pinkish tinge(if TNT was not completely removed by sellite) indicates the presence of DNT. Other reagents, such as diethylaminoethanol, may be used. This colors TNT deep violet and does not color DNT if used in neutral media. but colors it blue-green if alkali is present

DNT may also be detected and separated from TNT & MNT by chromatographic methods, as described in Refs 2,5 & 6

*Quantitative Tests for Cheddites:* a)Extract with ether for 6-7hrs in a Soxhlet(or other extractor) a 10.0g sample and transfer the extract to a tared beaker b)Evap the ether at 60°(3-4hrs) and leave the beaker overnight in a desiccator with concd sulfuric acid. Weigh the beaker to obtain the wt of ingredients, such as nitrocomps, vaselin, castor oil, etc c)Remove from beaker a 0.3-0.5g sample(accurately weighed) and determine its nitrogen content by Kjeldahl method, as modified by Williams d)If presence of PA is suspected, treat (with warm distd water) about one-half (accurately weighed) of the material left in the beaker; filter the extract and treat the filtrate with a 10% soln of nitron base in a 5% AcOH soln; separate the resulting ppt of nitron picrate by filtration, dry it and weigh e)Examine the material left after removal of PA, in small portions for other nitrocompds using the same procedures as indicated under Qualitative Tests f)Weigh accurately the last portion of material left in the beaker(See opn d) and treat it in cold with 10% Na or K hydroxide soln. This treatment dissolves nitrocompds, leaving oily and greasy substances(such as castor oil, vaselin, etc) as residue. Wash this residue with w, dry and weigh g)Examine the non-extractable material which was left in Soxhlet(See opn a), first by drying and weighing it h)Shake the sample(in a flask) with several small portions of hot w, decanting the soln each time into a tared, small, sintered glass filtering crucible of medium porosity. Any residue in the flask should be transferred quantitatively to the crucible and the latter washed with hot distd w i)Collect the filtrate and washings, cool them and transfer to a 100ml vol fl. Add dist w to the mark j)Pipette out a 100ml aliquot into a 500ml beaker and add 100ml of 5% AcOH soln contg 10g of nitron base. Separate the resulting ppt of nitron chlorate(or nitron perchlorate) by filtration thru a sintered glass crucible , which is not the same as in opn h k)Wash the crucible and contents with 75-100ml of 1% AcOH soln, dry, cool and weigh l)Calculate the percentage of chlorate(or perchlorate) by multiplying the wt by a factor, which is 0.3092 for $KClO_3$, 0.2686 for $NaClO_3$, 0.3360 for $KClO_4$, 0.2970 for $NaClO_3$ and 0.2849 for $NH_4ClO_4$ m)Dry the crucible with residue (See opn h) at 100-10°, cool and weigh. This residue might be carbon, sawdust, cellulose, collodion cotton, etc n)Determine, if required, other props of the Cheddite, such as moisture, acidity(or alkalinity), thermal stability, density, brisance, power, detonation velocity, etc(See also Ref 1,pp 138-9 & Ref 11,pp 470-1)

Perchlorates in Cheddites may also be detd by methods similar to those used in analysis of composite proplnts, as described in Ref 4

*Quantitative Determinations of DNT, MNT and TNT in Cheddites.* As *drip oil*(mixt of impure DNT, MNT & TNT) is often used for manuf of Cheddites, it is necessary to know how to determine these ingredients

The following two methods, taken from Ref 3 (which is now out of print), are fairly rapid and reliable

*Method 1,* (Developed during WWII by A. Zabenko at Volunteer Ordnance Works of Hercules Powder Co, Chattanooga, Tenn). In this method, a sample in which MNT has been detected(such as by odor) is treated with mixed nitric-sulfuric acid of the strength required to nitrate MNT to DNT and the amt of nitric acid consumed is detd by titrating the excess with standard ferrous sulfate soln

*Procedure.* Weigh accurately in a 15ml weighing bottle a 5g sample and drown the ensemble in 100ml of 95% sulfuric acid contained in a 250ml beaker. Add slowly, while stirring by means of a short thermometer, from a weighing

pipette about 10g of accurately weighed "standard" mixed acid keeping the temp in beaker below 40°. Cover the beaker with a watch glass and allow to stand for 15mins. Place the beaker in an ice-salt bath and titrate the soln with standard ferrous sulfate soln (1ml of which corresponds to 0.02g $HNO_3$) to a permanent faint pink color. Keep the temp in the beaker below 40°

% MNT = $[(W_1 \times C - R \times E) \times (2.1736 \times 100)] / W$, where $W_1$ = wt of std mixed acid; C = % $HNO_3$ in mixed acid; R = mls std $FeSO_4$ required, minus 0.2ml; E = grams of $HNO_3$ equivalent to 1ml of std $FeSO_4$; and W = wt of sample

*Note1:* Titration as described here does not give as accurate results as the "back titration" method described under Cellulose Nitrate, Analytical Procedures, p C 119-R

*Note 2:* For prepn of "standard" ferrous sulfate soln dissolve 176.5g of $FeSO_4.7H_2O$ in 400ml distd w contained in a 1000ml vol fl and add slowly, while stirring, 500ml of cold 1:1(by vol) sulfuric acid. After addg distd w to the mark, transfer to a dark reagent bottle for storing. Drop inside the bottle a piece or iron wire(or nail) to prevent the oxidation of ferrous to ferric ion

*Note 3:* Instead of using the above reagent, the ferrous ammonium sulfate soln may be used. Its prepn and standardization with K nitrate soln are described under Cellulose Nitrate, Analytical Procedures, p C119-R

*Note 4:* For prepn of "standard" mixed acid, add slowly, while stirring, from a weighing pipette, 115ml of 80% CP nitric acid to 2200ml of concd sulfuric acid contained in a large beaker which is cooled in an ice-salt bath. Transfer the soln to a brown glass-stoppered bottle and keep in a cool place

*Note 5:* For detn of % $HNO_3$ in std mixed acid, transfer from a weighing pipette 5-8g, accurately weighed sample of acid to a 250ml beaker contg 100ml of 95% sulfuric acid. Place the beaker in an ice-salt bath and titrate with std ferrous sulfate soln until a permanent faint pink coloration

%$HNO_3$ = $[(R \times E) \times 100] / W_1$, where R = mls std $FeSO_4$ required, minus 0.2ml; E = grams of $HNO_3$ equivalent to 1ml of std $FeSO_4$; and $W_1$ = wt of std mixed acid (Ref 3,pp 133-4)

If more accurate results are desired, use the "back titration" method described under Cellulose Nitrate, Analytical Procedures, p C119-R

*Note 6:* The above Method 1 of Zabenko is used for detn of MNT in its mixts with DNT & TNT. In order to determine the amt of DNT in these mixtures, use Method 2, which follows

*Method 2*(Developed During WWII at Keystone Ordnance Works, Meadville, Pa). Triturate in a medium size mortar a 10.0g sample with ca 50ml of $CCl_4$, allow to settle and decant the liq into a 500ml separatory funnel. Repeat this opn 3 or 4 times, transferring each time the liq into the same funnel. Shake the contents of funnel for 1min with an equal vol of 17% Na sulfite("sellite") soln (which was previously slightly acidified with $H_2SO_4$) and allow to stand until two layers separate. Transfer the bottom layer(soln of DNT in $CCl_4$) into a beaker and discard the red, top layer(sellite with products of decompn of TNT). Transfer the $CCl_4$ soln back into the same funnel and repeat the washings twice with fresh sellite solns. Then place 2 drops of $CCl_4$ soln into the hollow of a porcelain spot plate and add 5 drops of freshly prepd concd soln of KOH in 1:1 alc-acet mixt. If the color developed on this addn is not purely blue, but has a pinkish tinge, repeat washing with sellite once more and then transfer the $CCl_4$ soln to a tared dish. Evaporate the contents on a water bath, under the hood(avoiding inhaling the vapors of $CCl_4$ which are very toxic), cool the dish in a desiccator and weigh

% DNT = $(W_1 \times 100) / W = W_1 \times 10$ where $W_1$ = wt of dried residue and W = wt of sample(10.0g)

% TNT = 100 - % DNT

If DNT content is small(such as below 10%), while the bulk of material is TNT, another procedure, also described in Ref 3(See pp 136-7), might be found more convenient. As "drip oil" used in Cheddites always contains more than 10% of DNT, the other procedure is not discussed here

DNT may also be detd by titanous chloride buffer method as used by Butts et al for analysis of smokeless proplnts(Ref 3a)

Chromatographic procedures described in Refs 2,5 & 6 and IR(infrared) method described in Refs 7,8,9,10,12 & 13 can also be used for quantitative detns of nitrocompds in Cheddites (See also Chlorates, Analytical Procedures and under individual chlorates)

*Refs:* 1)M.Giua, SS **17**, 137-9(1922)(Chemical analysis of Cheddites) 2)Dr Halfter, SS & NC

**38,** 173-5(1943)(Sepn of DNT from TNT by chromatographic method) 3)Clift & Fedoroff, vol 4(1946), 133-4(Quantitative methods for detn of MNT in mixts with DNT & TNT); 134-7 (Qualitative and quantitative methods for detn of DNT in mixts with TNT) 3a)P.G.Butts et al, AnalChem **20,** 947-8(1948)(Detn of DNT in proplnts) 4)W.B.Meldrum et al, AnalChem **20,** 949-50(1948)(Detn of K chlorate in proplnts) 5)T.C.J.Ovenston, JSCI **68,** 58(1949)(Detn of expls, including 1-MNN; 1,3-DNB; 2,4-DNT; 1,3,5-TNB; 2,4,6-TNT; 2,4-DNPh & 2,4,6-TNPh by chromatographic methods) 6)Chi-Shau Ling, JChineseChemSoc **18,** 135-6(1951)(in Engl) & CA **46,** 2965(1952) [Sepn of 2,4-DNT from other nitrated products of toluene by chromatographic method. For this a soln of crude nitrated toluene (50g) in 500ml acetone is poured thru a 5.2cm column consisting of 80g pure magnesia, at the rate of 1 drop per sec and then the column is dried. TNT, being strongly absorbed, produces a violet zone at the top of the column; DNT, being poorly absorbed, forms a green zone at the bottom; and MNT and other products pass thru the column unadsorbed. DNT may be removed from lower zone by extraction with 95% ethanol followed by evapn & crystn. The same procedure may be used for extraction of TNT from upper section of column] 7)F.Pristera, Applied Spectroscopy **7,** No 3, 115-21(1953) & CA **48,** 1683(1954)(Infrared method for detg TNT & 2,4-DNT in admixts such as found in exudates) 8)F.Pristera & M.Halik, PATR **2013**(1954); AnalChem **27,** 217-22(1955) & CA **49,** 8744(1955)(IR method for detg o-, m-, & p-MNT's and 2,4- & 2,6-DNT's in mixtures) 9)F.Pristera, PATR **2254**(1956) [Analysis of expls by IR method; 68 spectrograms are given, among them are $\alpha$-MNN; 1,5- & 1,8-DNN's; MNB; m- & p-DNB's; 1,3,5-TNB; p-MNPh; 2,4-DNPh; 2,4,6-TNPh; o-, m- & p-MNT's; 2,4- & 2,6-DNT's; $\alpha$(2,4,6)-, $\beta$(2,3,4)- & $\gamma$(2,4,5)-TNT's; AN & Amm picrate] 10)W.E. Fredericks & F.Pristera, PATR's **2485**(1958) & **2546**(1958)(IR method for detg MNT's, DNT's & TNT's in admixts) 11)Giua, Trattato, **6**(1959), 470-71 12)W.E.Fredericks & F.Pristera,PB Report **137467** & CA **54,** 12585(1960)(Same info as in PATR **2546** of Ref 10) 13)F.Pristera et al, AnalChem **32,** 495-508(1960) & CA **54,** 1285-86(1960)(Analysis of expls by IR spectroscopy) 14)Anon, "Analysis for Powders and Explosives", AB Bofors Nobelkrut, Bofors, Sweden(1960), 148-50(Analysis of substances, such as K chlorate & perchlorate used as ingredients of Cheddites) 15)Dr Omero Vettori of Società Italiana Esplosivo Cheddite, Torino, Italy; private communications(1962)

**Cheddite-Type Explosives Containing Azobenzene.** See p A647-L in Vol 1 of this Encyclopedia

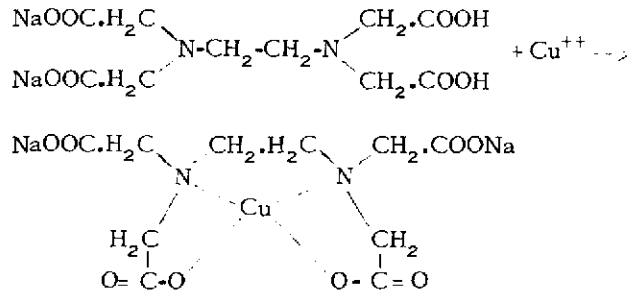
**Cheddite-Type Explosives Used in Finland.** See I.Huhtanen, Explosivst **1960,** 189-94

**Cheese Sticks.** Long pieces of Cordite, coated with Amm oxalate & shellac, which were used, instead of fuses, squibs, etc, in British South Africa for igniting blasting expls. They were also authorized for use in England

*Refs:* 1)Marshall **2**(1917), 540 2)Marshall, Dict(1920), 21 3)Thorpe **2**(1938), 525

**Chelation and Chelatometry.** Chelation(derived from the Gr word "kelos" which means "claw") is a chemical reaction in which some polyvalent metallic ions(such as $Cu^{++}$) react with organic compds("chelating agents") which contain functional groups(such as -OH, $-NH_2$ or -COOH) to form extremely stable, water soluble complexes, called *chelates.* The polyvalent metal in solns of chelates is chemically unreactive and cannot be detected by ordinary chem tests. The term "chelation" is sometimes also used to include "hydrogen bonding"

A typical example of "chelation" is formation of "Versene Copper Chelate", from Versene(one of the Dow chelating agents) and the copper ion:



In chelated Versene, the copper ion has become a member of an inner ring structure in the molecule and is inactivated. It will remain so unless it is desired to reverse the process, such as in polymerization of synthetic rubber

Chelates find numerous applications in chemical industries and in some analytical procedures, including those used in explosives labs(see CA's under Chelatometry)

An example of application of chelatometry to analysis of expls is given under Ref 6
*Refs:* 1)H.Diel, ChemRevs **21**, 39-111(1937) (the chelate rings) 2)Kirk & Othmer **4**(1949), 382(under Coordination Compounds) 3)Karrer (1950), 520 4)A.E.Martell & M.Calvin, "Chemistry of the Metal Chelate Compounds", Prentice-Hall, NY(1952) 5)Anon, C & EN **1956**(Feb 27), 956-7(The chemistry of chelation) 6)J.Vřeštál et al, ChemPrůmysl **6**, 50-2(1956) & CA **50**, 14229(1956)(Chelatometric method suitable for detn of lead in expls, such as Pb picramate, -styphnate, -azide or -picrate is described) 7)CondChemDict(1961), 248-9 8)S.Patai, "Glossary of Organic Chemistry", Interscience, NY(1962), 39

**Chemecol**(Spelled "Chemocol" in Ref 1). It is a chemico-mechanical device(developed by Du Pont Co) which breaks coal from the mine face by the force of compressed gas which is generated by chemical reaction within the device and is released mechanically. Chemecol assembly consists of a long, narrow, steel tube, closed at one end by a plug equipped with electrical connections, and, at the other end, by a rupture disc held in place by a discharge head. Inside this tube is a gas generating unit composed of a "starter mix" and a "pressure mix"(usually a non-detonating AN-fuel mix). A metallic, conductive, starter ribbon is imbedded in the starter mix and this ribbon is connected electrically to the plug and then(thru a cable) to a 36 volt storage battery. Usually several Chemecol tubes are placed in a borehole drilled in the coal face and the tubes may be discharged either one at a time, or multiple connections may be made to discharge several tubes at a time. In order to start the gas generating reaction, it is sufficient to pass a current of ca 8amps thru the ribbon for 6 to 10secs. Once started, the reaction continues to liberate gas until a predetermined pressure, such 15-20 thousand psi, is reached. Then, the disc is ruptured and the gas rushes out thru the ports in the discharge tube and breaks the coal, without danger of igniting the mine gas or coal dust. Prior to rupture of disc, breakage or disintegration of starter ribbon takes place and this interrupts the circuit of battery, thus eliminating the possibility of formation of an elec spark which might ignite coal gas released at the time of breaking of the disc

Chemecol is considered as one of the safest and efficient devices for breaking coal and it can be used in most dangerous gaseous and/or dusty coal mines(Refs 1,2,3 & 4)

Other devices, similar to Chemecol are:
*Airdox* - operated by compressed air, mentioned in Vol 1, of Encyclopedia, p A117-R and described in Ref 4,pp 137-42.
*Armstrong* - operated by compressed air, mentioned in Vol 1 of Encyclopedia, p A485-L and described in Ref 4,pp 137 & 140-42
*Cardox* - operated by gas produced on heating liquid carbon dioxide, briefly described in Vol 2 of this Encyclopedia and more completely in Ref 4,pp 123-7 and
*Hydrox* - operated by gas produced on heating a mixt of Na nitrate & Amm chloride(See Ref 4, pp 127-33)
*Refs:* 1)Anon, "DuPont Invention Points to New Era in Coal-Mining", C & EN **29**, 1745 (1951) 2)Blasters'Hbd(1952), 79-82 3)Cook (1958), 16 4)Taylor & Gay(1958), 133 and Plate 9 facing p 160

**Chemical Aerial Bombs.** See under Chemical Bombs

## CHEMICAL AGENTS or CHEMICAL WARFARE AGENTS(CWA)

(Agents chimiques or Gaz de combat in Fr; Chemische Kampstoffe, Kampfstoffe or Gaskampfstoffe in Ger; Aggressivi, Aggressivi chimice or Gas di guerra in Ital; Agresivos químicos or Gas de guerra in Span; Otravliayushchiye Veshchestva(OV), Boyevyiye OV, Boyevyiye Gazy or Boyevyiye Khimicheskiye Veshchestva in Rus). CWA's are chemical items(except explosive and pyrotechnic compns) used for military purposes, both offensive and defensive. The most important of these items are substances known as "war gases" or "poison gases". These are used to produce lethal, injurious or irritant effects resulting in casualties

Under the term of "chemical agents" are also understood items used for starting fires in enemy installations, houses, ships, or vehicles(see under INCENDIARY WARFARE) as well as substances producing smokes serving for screening movements of troops, ships, trains, or vehicles(See under SMOKES IN WARFARE)

Smokes producing compns used for signalling purposes(such as colored smokes)

are usually classified as pyrotechnic items *Historical*. The use of poisonous materials for military purposes was known in Biblical times. These poisons were obtained from plants or snakes, and poisoning of food, wine or water produced many casualties among enemy troops. Poisons were also used to smear tips of arrows and, when firearms came into use, some poisonous bullets were made. It does not seem that such bullets are used now but poisonous arrows are still used by some natives in Africa, Asia and Australia

Use of smokes, fumes or gases to produce casualties is also a very old practice. Smoke and fumes produced on slow-burning of green wood(w or w/o resins, pitch, sulfur or arsenic) was used by some ancients to drive out men and animals from caves or other dwellings(Ref 16,p 13-20). The earliest recorded attack, which may be considered as "chemical gas" took place during the Peloponesian War(431 to 404BC) when Spartans directed the fumes produced on burning green wood(mixed with tar, sulfur and arsenic) towards the besieged Athenians in towns of Plataea and Delium (Ref 16,p 20 & Ref 59,p 420). Another example of chemical attack took place in 187BC when the people of Ambrajia drove out the Romans (who besieged their town) by means of fumes produced from barrels filled with feathers and glowing coals(Ref16,p20). Poisonous fumes produced on burning of green wood(w or w/o other substances) were used in many wars including the Franco-Algierean War when Gen Pélissier succeeded in suffocating a great number of natives(Kabyls) by burning large quantity of green wood and directing the fumes against the natives. This took place in 1845 (Ref 16,p 21)

More effective chemical agents were proposed during Crimean War(1853-56) and during Amer Civil War(1861-65). These included sulfur dioxide, suggested by Brit Gen Dundonald, for use against the Russians besieged in Sevastopol (Ref 16,p 21) and Amer proposals to use chlorine, cacodyl, cacodyl oxide or an irritating gas produced on heating a mixt of sulfuric and hydrochloric acid(Ref 53). None of these materials, however, was applied in practice

Modern chemical warfare began with the German gas attack at Ypres, France on April 22, 1915, when 5700 cylinders filled with chlorine gas, were blown against French and Canadian trenches. This first gas attack was the most effective one of the entire WWI, because it met the Allied Armies both unprepared and unprotected. May casualties were caused by this attack(Ref 16,pp 21-2 & 42). In early subsequent attacks, the asphyxiating gases, such as compressed chlorine or phosgene, were released from containers(in which they were kept under pressure) at a time when the wind was blowing towards the enemy lines. This was known as "gas-cloud method". Later this procedure was replaced by the use of "chemical shells" which were filled with chemical agents. On bursting of these shells, the chemicals were scattered in the air inflicting damage where required. The Allies immediately followed the Ger example and soon surpassed the Ger efforts. This type of warfare was widely used thruout WWI

Although "chemical warfare" was outlawed after WWI by the Hague Convention, all great nations were prepd before and during WWII to resort to this kind of war again, and many new "chemical agents" were developed. The most prolific in this respect were the Germans, who developed, among other compds the so-called "nerve gases"(Refs 35 & 52). None of the nations ventured, however, to use during WWII any asphyxiating gas, although smokes and, especially, incendiaries were used to a great extent

US chemical agents are subdivided, accdg to the "Ordnance Corps Manual" ORD M 7-224 (Ref 36), into three groups: *Group A* consists of "blister"gases, such as H, HD, HN, and L. They are the most dangerous to handle and require for protection not only a gas mask but special clothing, including heavy rubber boots and heavy rubber gloves; *Group B* consists of nonpersistent(choking, blood & nerve-, tear- and vomiting-) gases,(such as CG, PS, AC, CK, DA, DM, CL, CNS and CNB) and smokes(such as FM and FS). They require for protection gas masks and gloves. Personnel handling liquid acid-type chem agents should wear also rubber boots and aprons; *Group C* includes WP and PWP and should be handled by personnal equipped with flame-proof gloves & coveralls, and chemical safety goggles

The majority of agents prepd or investigated in US have been assigned "symbols" or other names which have no relationship to their chem compns. These agents are listed below in alphabetical order of their code letter. No classified information is included here

**AC.** Hydrogen Cyanide or Prussic Acid(Fr Vincennite or Manganite), HCN; col liq with odor of bitter almonds, bp ca 78°F(25.6°); lethal when inhaled; one of the "blood" gases (Group B, nonpersistant chem agents)(Ref 16,p 242 & Ref 36,p 29-27)

**BA.** Bromoacetone(Fr Martonite, Ger B-stoff), $Br.CH_2.CO.CH_3$; col liq, bp 136.5°; violent irritant, mainly for the eyes; was used during WWI(Ref 16,pp 142 & 172)

**BBC or CA.** α-Bromobenzylcyanide(Fr Carnite), $C_6H_5.CH(CN)Br$; yel crysts melting at 17°F (25°) to a brownish oil, which boils at 437°F(ca 225°) giving a heavy vapor of soured fruit odor; it is one of the tear gases(Ref 16, pp 181 & 292; Ref 25a, p 172)

**CDA.** Accdg to Bebie(Ref 22,p 63) it is CW symbol for Diphenylcyanoarsine. See DA

**CG.** Phosgene or Carbonyl Chloride(Fr Collongite, Ger D-Stoffe), $COCl_2$; col liq with odor of fresh cut hay, bp 47°F(8.3°); when inhaled causes pulmonary endema(Group B, nonpersistent)(Ref 16,p 154; Ref 25a,p 170 & Ref 36,p 29-24)

**CK.** Cyanogen Chloride(Fr Vitrite or Mauguinite), CNCl; col liq with pungent odor, bp 55°F (12.8°); lethal when inhaled(Group B, non persistent)(Ref 16,p 248 & Ref 36,p 29-28)

**CL.** Chlorine(Fr Bertholite, Ger Chlor), $Cl_2$; grn-yel gas with pungent odor, bp -30°F(-34.4°); lung irritant often lethal(Group B, nonperistent) (Ref 16,p 151; Ref 25a,p 171 & Ref 36,p 29-30) (See also Chlorine)

**CN.** Chloroacetophenone or Phenacyl Chloride, $C_6H_5.CO.CH_2Cl$; greyish solid with fruity odor, mp 129°F(54°); it is a strong tear-producing substance(Ref 16,p 176 & Ref 36,p 29-29

**CNB.** Soln of CN in mixt of benzene and $CCl_4$; fr p 19°F(-7.2°); acts as tear gas(Ref 36,p 29-31 & Ref 54a,p 67)

**CNC.** Soln of CN in chloroform; acts as tear gas(Ref 54a,p 67)

**CNS.** Soln of CN in mixt of PS(chloropicrin) & Chloroform; fr p 35°F(1.7°); acts as tear gas (Ref 36,p 29-30 & Ref 54a,p 67)

**DA.** Diphenylchloroarsine(Ger Clark I), $(C_6H_5)_2AsCl$; a viscous semi-solid mass varying in color betw wh & blk; mp 111°F(ca 44°); gives on heating an aerosol causing skin & eye irritation, chest distress and nausea (Ref 16,pp 143 & 196; Ref 36,p 28-29). It is one of the vomiting gases(Ref 54a,p 67)(See also Ref 22,p 63). This compd is designated in Ref 25a,p 173 as PD(qv)

**DC.** Diphenylcyanoarsine(Ger Clark II), $(C_6H_5)_2AsCN$; solid; dispersed by heat; it produces an aerosol, irritating respiratory passages and causing nausea and headache. It is one of the "vomiting" gases(Ref 16,pp 199-201 & Ref 54a,p 68)

**DM.** Adamsite or Diphenylaminechloroarsine, $HN(C_6H_4)_2AsCl$; grn-yel to blk solid, mp 383°F(ca 195°); dispersed by heat to produce an aerosol causing skin and eye irritation, headache and nausea(Ref 16,p 206; Ref 25a,p 172; Ref 36,p 29-29). It is one of the "vomiting" gases(Ref 54a,p 67)(See also Vol 1,p A491-R under Arsine Derivatives, Organic)

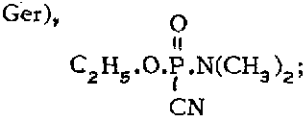
**DP.** Diphosgene or Trichloromethylchloroformate (Fr Surpalite; Ger Perstoff), $Cl.COO.CCl_3$; oily liq with musty hay odor, bp 260.6°F (ca 127°); acts as lung irritant similarly to CG(Ref 16,pp 154-5 & Ref 25a,p 170)

**ED.** Ethyldichloroarsine(Ger Dick or Grünkreuz -3), $C_2H_5.AsCl_2$; oily liq with biting pepper -like odor; bp 312°F(ca 156°); acts as lung irritant(Ref 16,pp 143 & 195-6; Ref 25a,p 168) (See also Vol 1,p A491-R, under Arsine Derivatives, Organic)

**FM.** Titanium Tetrachloride(Ger F-Stoff), $TiCl_4$; heavy, col liq which solidifies at -9°F(ca -23°); bp 277°F; produces in moist air dense white clouds with acrid odor(Ref 16, p 269; Ref 25a,p 174; Ref 36,p 29-31 & Ref 54a,p 69)

**FS.** Sulfur Trioxide in Chlorosulfonic Acid (55/45), $SO_3$-$SO_3HCl$; heavy liq with pungent odor; fr p -22°F(-30°); fumes strongly in air producing dense white smoke(Ref 16,p 268; Ref 25a,p 174; Ref 36,p 29-32 and Ref 54a, p 68)

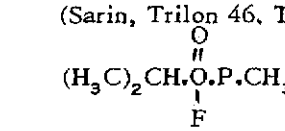
**GA.** Ethylphosphorodimethylamidcyanadate or Monoethylester of dimethylaminocyano-phosphoric acid(Tabun, Trilon 83, T83 or T100 in Ger),



$C_2H_5.O.P(=O).(CN).N(CH_3)_2$;

col to dk-brn oil; was first prepd before WWII in Germany and Switzerland and planned to be used in Chem bombs and rockets(Ref 52,p Ger 204 & Ref 55)

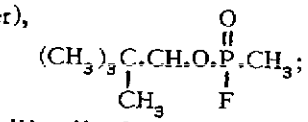
**GB.** Isopropylmethylphosphonofluoridate or Isopropylester of methylfluorophosphoric acid (Sarin, Trilon 46, T46 or T114 in Ger),



$(H_3C)_2CH.O.P(=O)(F).CH_3$; col & odorless, very

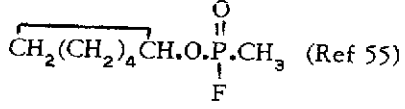
volatile liq,about 3 times as toxic as GA; quick-acting agent of medium persistency; was first prepd before WWII in Germany and Switzerland(Ref 52,p Ger 204; Ref 54a,p 68 & Ref 55)

**GD.** Pinacolylmethylphosphonofluoridate or Pinacolicester of methylfluorophosphoric acid(Somon in Ger),



col, camphor-smelling liq; less volatile but more toxic than GB; was first prepd before WWII in Germany and Switzerland(Ref 52,p Ger 204 & Ref 55)

**GF.** Cyclohexylmethylphosphonofluoridate or Cyclohexylicester of methylfluorophosphoric acid,



(Ref 55)

**H**(or HS). Mustard Gas, Thiodiglycol Chloride or Dichloroethyl Sulfide(Fr Yperite; Ger Lost or Gelbkreuz), $S(CH_2.CH_2.Cl)_2$, brn oily liq with horseradish or garlic odor, fr p ca $50^{\circ}F(10^{\circ})$; causes blistering(vesicant) effect on the skin. It is a persistent chem agent belonging to Class A, which is the most dangerous to handle(Ref 16,pp 221-39; Ref 25a,p 166; Ref 36,p 29-10 and Ref 54a,p 68)

**HC.** Mixture of hexachloroethane, $Cl_3C.CCl_3$, with Zn dust, $NH_4ClO_4$ & $NH_4Cl$; produces on burning a grayish-whitesmoke which serves for screening(Ref 16,p 270 and Ref 25a,p 174)

**HD.** Distilled Mustard(purified H); amber -colored oil, fr p $58^{\circ}F(14.5^{\circ})$; bp $433.6^{\circ}F$ $(223^{\circ})$ with decompn; practically odorless and much more difficult to detect than impure product; produces, the same effect as H(Ref 25a,p 166; Ref 36,p 29-10 & Ref 54a,p 68)

**HN.** Nitrogen Mustards are defined by Sartori (Ref 35,p 226) as tertiary 2,2'-dihalodialkyl-amines, more particularly 2,2'-dichlorodiethyl-amines of the structure, $R\text{-}N(CH_2CH_2Cl)_2$, in which R is an alkyl, haloalkyl or aryl group. The name "nitrogen mustards" is derived from the structure similarity to mustard gas(see H). They are also called "radiomimetric poisons" because many of their biological props are like those of ionizing radiations. Their toxic props are similar to those of H or HD. They were first prepd in Germany before WWII. A table listing 22 "nitrogen mustards" is given on p 228 of Ref 35. One of these CN-1 is listed in Ref 36,p 29-11 and three: CN-1, CN-2 and CN-3 in Ref 52a,p 68, but their compn is not given. It is mentioned, however, that they produce more permanent damage than H or HD. Since WWII, these compds have been studied in US and GtBritian

**HT.** Symbol for CWA called "Mustard Gas Agent T"(Ref 54a,p 152)

**KT**(Brit). Tin Tetrachloride(Fr Opacite), $SnCl_4$; col liq, bp $136.4^{\circ}$; produces wh smoke which is not corrosive; was used during WWI in mixt with CG & PS in some shells(Ref 16,p 269)

**L.** Lewisite or Chlorovinyldichloroarsine(M1), $Cl.CH{:}CH.AsCl_2$; dk-grn oily liq with odor resembling that of geraniums; fr p $15^{\circ}F$(ca $-9.4^{\circ}$); it boils ca $374^{\circ}F(190^{\circ})$ yielding a dense vapor, acting physiologically similarly to H; in addn, it is a systemic poison when absorbed into the body thru the skin or lungs. It is less persistent than H(Class A of chem agents)(Ref 16, 202-6; Ref 25a,p 167; Ref 36,p 29-12 and Ref 54a,p 68) (See also Vol 1,p A491-R, under Arsine Derivatives, Organic).

**MD.** Methyldichloroarsine(Ger Methyldick), $CH_3.AsCl_2$; blister gas(Ref 16,p 143; Ref 22,p 101). Compare with ED and PD

**PD.** Phenyldichloroarsine(Fr Sternite), $C_6H_5.AsCl_2$. A liq which can be dispersed by expl action or as a spray to form a delayed action casualty gas of low persistency. Classed as "blister" gas, it also acts as vomiting gas (Ref 54a,p 68)

In Ref 25a,p 173, PD is listed as Diphenylchloroarsine(Compare with DA)

**PS.** Chloropicrin, Nitrochloroform or Trichloronitromethane(Brit Vomiting Gas; Fr Aquinite; Ger Klop), $Cl_3C.NO_2$; col liq with an odor resembling that of anise, bp 231.5-$234^{\circ}F$ (ca $147^{\circ}$); class B chem agent, intermediate in toxicity betw CL & CG(Ref 16,pp 158-61; Ref 25a,p 169; Ref 36,p 29-26 and Ref 54a,p 69)

**PWP.** Plasticized White Phosphorus. A finely divided WP suspended in gel of rubber and xylene. It is a smoke producing agent with side incendiary effects. Its action is similar to WP except that it is slower burning(Ref 36,p 29-41 & Ref 54a,p 68). Both PWP and WP are Class C chemical agents

**Q.** A chemical agent of specialized application (Ref 54a,p 68)(Its formula is secret)

**T.** A chemical agent of specialized application (Ref 54a,p 68)(Its formula is secret)

**TH1.** Thermite. An incediary chemical agent

composed of an intimate mixt of ca 73% FeO & 27% of finely granulated Al; used in items of ammo to provide a source of heat to cause fires at target(Ref 16,p 263; Ref 25a,p 176 and Ref 54a,p 68)

**TH2.** Thermate. An incendiary chemical agent composed of an intimate mixt of TH1 with a binder and an addnl oxidizer. It was formerly used as an igniter for magnesium bombs(Ref 54a,p 68)

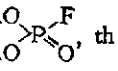
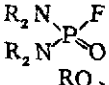
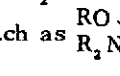
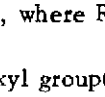
**VX.** Persistent chem agent. Its formula is secret, but its uses are discussed in unclassified "Assembly of Explosive Components", Technical Bulletin TB **9-1300-203-1**(1961)

**WP.** White(Yellow) Phosphorus. A lt yel waxy solid,mp 110°F(ca 43°), bp 549°F(ca 287°). It is chemically very active and upon contact with air burns with a luminous flame producing dense white smoke which is not toxic, unless it is very dense. When loaded in ammo, it is dispersed by a burster chge. It is very toxic if taken internally(Ref 16,p 262; Ref 25a,p 175; Ref 36,p 29-41 and Ref 54a,p 69)

In addn to the above US chemical agents (some of them probably obsolete), the following compds, which were developed during and after WWI, may be mentioned: a)Ethylchlorosulfonate(Fr Villantite), $C_2H_5.SO_2OCl$(lung injurant)(Ref 16,pp 142 & 208) b)Chloromethylchloroformate, $(Cl.CH_2).COOCl$ in mixt with Dichloromethylchloroformate, $(Cl_2.CH).COOCl$ was used as lung irritant, called in German "K-Stoff" or "C-Stoff"(Fr Palite)(Ref 16,pp 161-3). This mixt replaced Methylchlorosulfonate, $Cl.SO_2.OCH_3$(Ref 16,p 211) c) Dimethylsulfate(Fr Rationite; Ger D-Stoff), $(CH_3)_2SO_4$(blister gas)(Ref 16,pp 214-20) d) Phenylcarbylaminechloride(Ger "K2-Stoff"), $C_6H_5.NCCl_2$(lung injurant)(Ref 16,pp 253-5) e)Phenyldibromoarsine(Ger X-Stoff), $C_6H_5.AsBr_2$(lung injurant)(Ref 16,pp 201-2) f) Cyanogenbromide(Brit CB; Austrian CE; Ital Campiellite), CNBr(systemic poisoning)(Ref 16,pp 250-1) g)Benzylbromide(Fr Cyclite; Ger T-Stoff), $C_6H_5.CH_2Br$(irritant or tear gas)(Ref 16,pp 178-80) h)Benzyliodide(Fr Fraissite), $C_6H_5.CH_2I$(same as bromide)(Ref 16,p 180) i)Chloroacetone(Fr Tonite; Ger A-Stoff), $CH_3.CO.CH_2Cl$(irritant or tear gas)(Ref 16,pp 142 & 171-2) j)Bromoacetone. See CW symbol BA k)Martonite, Fr chem agent consisting of bromoacetone 80 & chloroacetone 20%(Ref 16,p 176) l)Bromomethylethylketone, $BrCH_2.CO.C_2H_5$. Its mixt with Chloromethylethylketone, $ClCH_2.CO.C_2H_5$ was used by the French, as a tear gas, under the name of Homomartonite (Ref 16,pp 175-6) m)Dibromoethylsulfide(Fr Bromlost),$(Br_2CH_2.CH_2)_2S$(blister gas)(Ref 16,p 292). Compare with Mustard Gas(CW symbol H or HS) n)Ethyliodoacetate(Brit SK), $C_2H_5.OOC.CH_2I$(tear gas)(Ref 16,pp 164-5) o)Dichlorodimethylether, $ClH_2C.O.CH_2Cl$ (acts like CG)(Ref 16,pp 166-7) p)Dibromodimethylether, $BrH_2C.O.CH_2Br$(acts like CG)(Ref 16,pp 167-8) q)Bromoxylene, $C_6H_4(CH_3)(CH_2Br)$ and Dibromoxylene, $C_6H_4(CH_2Br)_2$ (tear gases)(Ref 16,pp 182-3) r)Perchloromethylmercaptan, $Cl_3C.SCl$(irritant)(Ref 16,pp 213-14) s)Thiophosgene(Fr Lacrimite), $SiCCl_2$(tear gas)(Ref 16,p 214) t)Methylcyanoformate, $CH_3.O.CO.CN$ and Ethylcyanoformate, $C_2H_5.O.CO.CN$. A mixt of these products with the addn of ca 10% of the esters of chloroformic acid was used by the Ger Army during WWI under the name of "Cyclon"(Ref 16,pp 251-3) u)Daisite,Fr thermite mixts(Ref 16,p 265) v)Brit "S" Mixture produced brn-yel smoke of low screening power(Ref 16,p 268) w)Brit "KT" (Fr Opacite), $SnCl_4$ - was used in some Fr smoke shells in mixt with phosgene(see CG) and chloropicrin(see PS)(Ref 16,p 269)

Several hundred new chemical agents were developed and tried in Germany before and during WWII(Ref 52,p Ger 28), the most important of them was a group of **Trilons**, which included *Tabun*, *Sarin*("nerve gas") and *Somon*(Ref 52,p Ger 204). Tabun and Sarin are also described in Ref 35,pp 253-4

Sartori(Ref 35) described under the title of "New Chemical Warfare Agents", the following compds: *Nitrogen Mustards*(Ref 35,pp 226 & 228)(See also under CW symbol HN); *Fluroacetates*, which comprise the esters of fluoroacetic acid and of higher ω-fluorocarboxylic acids of the general formula $F(CH_2)n-COOR$. The first compd of this series, methylfluoroacetate, $FCH_2COOCH_3$, was prepd in 1896 by Swarts but possibility of its use as CWA was not discovered until shortly before WWII. Many other fluoroacetates were prepd and investigated before and during WWII. It was planned to use some of them as water contaminants(Ref 35,pp 236-7). In tables 3,4, 5,6 & 7 of Ref 35 are listed various fluoroacetates. As a rule, they are highly

toxic when inhaled and to a lesser extent when absorbed thru the skin; *Fluorophosphates* are comprised of the diesters of fluorophosphoric acid  , the substituted diamidophosphoryl fluorides  and related substances, such as  , or  , where R is an alkyl, aryl or cycloalkyl group(Ref 35,pp 245-6). In tables 8,9 & 10 of Ref 35, are listed several of these compds

*Refs:* 1)Pascal(1930), 247-302(Gaz de combat) 2)Ullmann **6**(1930)(Kampfstoffe, Chemische),pp 419-33(not found in new edition) 3)Anon, "A Handbook of Chemical Warfare Agents", US GovtPtgOff, Washington,DC(1931) 4)A. Izzo, "Guerra Chimica e Difesa Antigas", Hoepli, Milano(1933) 5)M.Sartori, "Die Chemie derKampfstoffe", Vieweg, Braunschweig (1935) 6)R.Hanslian, "Der chemische Krieg", I(Militärischer Teil), Verlag von Mittler, Berlin(1936) 7)A.M.Prentiss, "Chemicals in War; A Treatise on Chemical Warfare", McGraw-Hill, NY(1937) 8)J.Meyer, "Der Gaskampf und die Chemischen Kampfstoffe", Hirzel, Leipzig(1938) 9)M.Sartori, "Chimica delle Sostanze Aggressive" , Hoepli, Milano (1938) and its Engl translation: "The War Gases. Chemistry and Analysis", Churchill, London(1939), 10)W.Kinttof, "Experiments in Warfare Chemistry", Massie PubgCo, London(1939) 11)Thorpe **3**(1939), 7-22(Chem warfare) 12)H.F.Thuillier, "Gas in the Next War", Goefrey Bles, London(1939) 13Anon, "The Detection and Identification of War Gas", ChemPubgCo, NY(1939) 14)A.Meyer", Les Gaz de Combat", Ch. Lavauzelle, Paris(1940) 15)W.Schweisheimer, MedRecord **154** , 196-8 (1941) & CA **36**, 185(1942)(Historical discussion on uses of poison gases, poisonous arrows and venomous snakes in war) 16)C. Wachtel, "Chemical Warfare", ChemPubgCo, Brooklyn, NY(1941) 17)M.B.Jacobs, "War Gases, Their Identification and Decontamination", Interscience, NY(1942) 18)F.A.Hessel, M.S.Hessel & J.W.Martin, "Chemistry in Warfare", Hastings House, NY(1942) 19)A.H.Waitt, "Gas Warfare", Duell, Sloane & Pearce, NY(1942) 20)C.D. Leake & D.F.Marsh, JChemEduc **20**, 339-43 (1943)(Action of war gases) 21)A.F.Claflin & F.C.Hickey, JChemEduc **20**, 351-7(1943) (Chem identification of war gases) 22)Bebie (1943), 29,38,44-5,47-8,53-4,56-7,62-5,70,79, 87,100-1,147-8, & 160-2 23)R.Agrelo & J.M. Franci, AnalesAsocQuímArgentina **31**, 30B (1943) & CA **38**, 2763(1944)(History & classification of war gases) 24)A.Izzo, "Guerra Chimica e Protezione Antigas", Hoepli, Milano(1944) 25)A.H.Waitt, "Gas Warfare", Published by Infantry Journal, Washington,DC(1944) 25a)Anon, "Ammunition Inspection Guide", TM **9-1904**(1944), 26)G.J.B. Fischer, "Incendiary Warfare", McGraw-Hill, NY(1946) 27)US Strategic Bombing Survey, "Powder, Explosives, Special Rockets, Jet Propellants, War Gases and Smoke Acid", Ministerial Rept No 1, Exhibits CD and CH, Oil Division, Washington,DC(1947) 28)Z.M. Bacq, ActualitésBiochim **8**, 1-48(1947)(Recent work on toxic war gases; a review with 60 refs) 29)USArmyChemicalCorps, "The Chemical Warfare Service in World War II", Reinhold, NY(1948) 30)W.A.Noyes, "Science in World War II", Little, Brown & Co, Boston (1948), 141-260(Chemical warfare agents); 274-91(Screening smokes); 292-5(Toxic aerosols); 318-32(Offensive chem warfare; 388-409(Incendiary bombs); 410-19(Incendiary fuels); 420-30(Flame -thrower development) 31)R.T.Williams "The Biochemical Reactions of Chemical Warfare Agents," UnivChicagoPress, Chicago(1948) 32)J.MacRae, AFCJ(Armed Forces Chemical Journal) **3**, No 7, 30-3(1950) & CA **44** 3179 (1950)(Chem warfare; a review of research progress during 1931 to 1949 incl) 33)A.C. Auliffe, AFCJ **3**, No 8, 28-9(1950) & CA **44**, 5037(1950)(Industry and Chemical Corps) 33a)G.Ljunggren, "Stridgaser och Gasskyd", Zivilverteidigungsverbandes, Stockholm(1950) 34)Kirk & Othmer **7**(1951), 117-45(Gas warfare agents) 35)M.Sartori, ChemRevs **48**, 225-57 (1951) & CA **45**, 5337(1951)(New developments in the chemistry of war gases; a review with 120refs) 36)Anon, "Ordnance Safety Manual ORDM **7-224**(1951),pp 29-11 to 29-51(Classification of chemical agents as A,B & C; packing, marking, handling, storage, fire hazard, shipping, first aid treatment and destruction) 37)Anon, "Field Behavior of Chemical Agents", TM **3-240**(1951) 38)E.F.Bullene, AFCJ **5**, No 4, 4-7(1952)(Effectiveness of chem warfare) 38a)A.M.Prentiss, Jr, AFCJ **5**, No 3, 2-4 (1952) & CA **46**, 4699(1952)(Chem warfare in the Air Corps) 39)EncyclBritannica **5**(1952), 354-60(Chemical warfare), 39a)G.Castel-

franchi & P.Malatesta, "Lezioni di Chimica di Guerra", Ed Studium, Roma(1954) 40) Anon, "Chemical Filling and Handling Equipment", TM **3-255**(1955) 41)A.Kondritzer, US Armed Forces MedJ **7**, 791-6(1956) & CA **50**, 10308(1956)(Chemistry, detection and decontamination of nerve gases) 42)Anon, "Military Chemistry and Chemical Agents", TM **3-215**(1956) 43)Anon, "Medical Manual of Chemical Warfare", BritCrownCopyright, ChemPubgCo, NY(1956) 44)Anon, "Ground Chemical Munitions", TM **3-300**(1956) 45) G.Schenk, "The Book of Poisons", Swets & Zeitlinger, Amsterdam(1956)(Section on chem warfare agents) 46)A.Koblin & J.Epstein, AFCJ **11**, No 5, 24-7(1957) & CA **51**, 18392-3 (1957)(Field sampling and analysis of nerve gas) 47)B.Gehauf & J.Goldensen, Anal Chem **29**, 276-8(1957) & CA **51**, 6434(1957)(Detection and estimation of nerve gases by fluorescene reaction) 48)Anon, "Storage, Shipment and Handling of Chemical Agents and Hazardous Chemicals", TM **3-250**(1957) 49)Collier's Encycl **19**(1957), 332-38(Warfare, chemical) 50)J.Goldensen, AnalChem **29**, 877-9(1957) & CA **51**, 11940(1957)(Detection of nerve gases by chemiluminescence) 51)Anon, "Capabilities and Employment of Toxic Chemicals", TM **3-200**((1958) 52)PATR **2510**(1958),pp Ger 28 & 204(Some Ger chem warfare agents developed before and during WWII) 53)W.D.Miles, AFCJ **12**, No 2, 26-7 & 33(1959); CA **53**, 612(1959) (Chemical warfare agents proposed, but not accepted for use in Amer Civil War) 53a)W.D. Miles, AFCJ **12**, No 5, 34-6(1959) & CA **53**, 612(1959)(Chem weapons used in US ca 1825 included stink balls, fire rain and smoke pots) 54)M.Giua & M.Civera, "Aggressivi Chimici", pp 501-56 and L.Stefanini, "Fiammiferi",pp 559-609 in Giua's, "Trattato di Chimica Industriale", UTET , Torino, VI(1959) 54a) Glossary of Ord(1959) 55)D.N.Kramer et al, USP 2926072(1960) & CA **54**, 13502(1960) (Colorimetric detection by means of oximes, such as 4,4'-bis(dimethylamino)benzophenone oxime, of chemical warfare "G" Agents: GA,GB, GD & GF) 56)R.W.Pfeil, USP 2921791(1960) & CA **54**, 14510(1960)(Colorimetric detection of above G agents by means of a crayon consisting of di-Na diisonitrosoacetone hexahydrate 20, o-toluidine 20, urea 15, Li stearate 27, LiCl 3 & CaO 15%) 57)G.H.Gray, "Laboratory Handbook of Toxic Agents", Prentice-Hall, Englewood Cliffs, NJ(1961) 58)Anon, "Employment of Toxic Chemical Agents", TM **3-200A**(1961)(Conf)(Not used as a source of info) 59)Dr O.Eisenschiml, Chemist **39**, 421(Dec 1962) 60)US Military Specifications: MIL-C-357A, MIL-C-379A, MIL-C-10338B, MIL-C-10463B, MIL-C-10758C, MIL-C-51029 and others

**Chemical Ammunition.** Ammunition in which the filler has the basic function of producing a toxic or irritant effect on the body, a screening effect(smoke) or an incendiary action(See also Chemical Energy Ammunition, Chemical Bombs, Chemical Grenades,Chemical Gun. Howitzer and Recoilles Rifle Shells, Chemical Land Mines, Chemical Mortars & Chemical Mortar Shells, and Chemical Rockets
*Refs:* 1)Ohart(1946), 86,101,105,120,220,234, 268,290,355,357-8 & 362 2)Anon, "Ordnance Safety Manual", Dept of the Army ORDM **7-224**, C3, Paragraph 209(1954) 3)Anon, "Ground Chemical Munitions", TM **3-300**(1956)

**Chemical Ammunition, Destruction of.** See under Chemical Munitions; Destruction, Handling, Storing and Shipping of

**Chemical Ammunition, Testing of.** In testing bombs, grenades, or projectiles filled with poisonous gases, the firing and observation personnel must be equipped with gas masks and other necessary equipment. Direction of wind and its velocity must be taken into consideration before testing to prevent the liberated gases from endangering nearby localities
*Ref:* Anon, "Ordnance Safety Manual", ORDM **7-224**, C7(1958)

**Chemical Artillery Ammunition.** See Chemical Gun, Howitzer & Recoilless Rifle Shells and Chemical Mortar Shells

**Chemical & Bacteriological Warfare.** Chemical warfare (CW) is defined under Chemical, Biological and Radiological(CBR) Warfare. Bacteriological warfare, which may be considered as a branch of biological warfare, is conducted with ammunition(such as bombs) filled with deadly or sickness-producing bacteria
*Ref:* Glossary of Ord(1959), 28

**Chemical, Biological and Radiological(CBR) Warfare,** sometimes called: *Chemical,*

*Bacteriological(or Germ) and Nuclear Warfare.* Chemical warfare(CW) may be defined as the tactics and technique of using chemical agents (qv) in offensive action, or of employing defensive measures against such actions(Ref 12,p 69)

Biological warfare(BW) or Biowar may be defined as warfare waged by the employment of biological agents, such as viruses, certain microorgamisms, toxic bacteriological products, and chemical plant-growth inhibitors to produce death or casualties in man, animals, or plants; defense against such warfare(Ref 12,p 38)

Radiological warfare(RW) may be defined as the employment of agents or weapons to produce residual radioactive contamination,as distinguished from the initial effects of a nuclear explosion(blast, thermal, and initial nuclear radiation); defense against such warfare (Ref 12,p 233)

For more info on these types of warfare see Refs 1-11 & 13-21

(See also Chemical Agents)

*Refs:* 1)Refs for Chemical Warfare are the same as given under Chemical Agents 2)Anon, Ordn **32**, 76(Sept 1947)(Biological or germ warfare) 3)T.Roseburg, "Peace and Pestilence", McGraw-Hill, NY(1949) 4)AEC(Atomic Energy Commission), "The Effects of Atomic Weapons", McGraw-Hill, NY(1950) 5)J.DeMent, USPAppl 729875 (1952); Official Gaz **659**, 1104(1952); CA **47**, 978(1953)(Radioactive chemical warfare agents) 6)Anon, "Military Biology and Biological Warfare Agents", TM **3-216**(1956) 7)Anon, "Soldier's Handbook for Nuclear, Biological and Chemical Warfare", FM(Field Manual) **21-41** (1948) 8)Anon, "Small Unit Procedures in Nuclear, Biological and Chemical Warfare", FM 21-40(1958) 9)Anon, "Radiological Recovery of Fixed Military Installations", TM **3-225**(1958) 10)S.Kinsman et al, "Radiological Health Handbook", US Dept of Health, Education and Welfare, Cincinnati, Ohio(1959) 11)ICRP, "Recommendations of the International Commission on Radiological Protection", Pergamon Press, NY(1959) 12)Glossary of Ord(1959), 38(Biological Warfare or "Biowar"); 69(Chemical Warfare), and 233(Radiological Warfare) 13)Anon, "Research in CBR", Dept of the Army Pamphlet, No **3-2**(1960) 14)US Congress, Senate Committee on Foreign Relations", Chemical-Biological-Radiological Warfare and Its Disarmament Aspects", US GovtPrtg-Off, Washington, DC(1960) 15)Anon, "Nonmilitary Defense. Chemical and Biological Defenses in Perspective", Advances in Chemistry Series No **26**, ACS, Washington, DC(1960) 16)Anon, "Chemical, Biological and Nuclear Training Exercises and Integrated Training", FM **3-48**(1960) 17)H.L. Andrews, "Radiation Biophysics", Prentice-Hall, Englewood Cliffs, NJ(1961) 18)Anon, "Chemical, Biological and Radiological(CBR) Decontamination", TM **3-220**(1961) 19)Anon, "Chemical, Biological and Radiological(CBR) Operations", FM **3-5**(1961) 20)Anon, "Chemical and Biological Weapons Employment", FM **3-10**(1962) 21)B.H.Gundel, Ordn **47**, 435-7(1963) [Discussion on justification of using CB(Chemical & Biological) weapons in warfare]

**Chemical Bombs.** Under this name are bombs filled with a chemical agent(qv). Some US chemical bombs are listed in Vol 2 of this Encyclopedia under BOMBS and most Ger chemical bombs of WWII are listed in Ref 4

Some fairly recent US chemical bombs are listed in Refs 1,2 & 3, but none is listed or described in the latest edition of "Ammunition Complete Round Charts"(Ref 5). The "smoke bombs" described on sheets 13 & 14 of Ref 5 are used for signalling, and for this reason are classified not as chemical bombs but as pyrotechnic items

*Refs:* 1)Anon, "Chemical Bombs and Clusters", Dept of the Army Tech Manual TM **3-400**(1957) (Characteristics, nomenclature and marking of gas, incendiary and smoke bombs) 2) Anon, "Bomb, Gas, Nonpersistent, 750-lb, MC-1", Dept of the Army Tech Bulletin TB **3-400**(1958) 3)Anon, "Bomb, Fire, 750-lb, M116A2", TB **3-400**(1958) 4)PATR **2510** (1958),pp Ger 14-23 5)Anon, "Ammunition Complete Charts", Book III, "Bombs, Pyrotechnics, Grenades, Mines, Cartridge Actuated Devices, Rockets, Rocket Motors, Demolition Material, Miscellaneous Items of Ammunition", PicArsn, Dover, NJ(1961)

**Chemical Candles.** A device(now obsolete) consisting of a thin metal container filled with a chem agent and provided with a match-head which could be ignited by friction or electrically. These candles were used both for screening and harassing effects

*Ref:* Hayes(1938), 623

**Chemical Cannon Shells.** See Chemical Gun, Howitzer and Recoilless Rifle Shells; also Chemical Mortar Shells and Chemical Rockets

**Chemical Cellulose.** White fibers, consisting mostly of alpha-cellulose, obtained from vegetable matter(such as wood or cotton linters) by treatment with sulfite dilute NaOH soln or other reagent. Material obtained by treatment of cotton linters with dilute NaOH is also known as *chemical cotton*
(See also CELLULOSE AND DERIVATIVES)
*Ref:* Merriam-Webster's(1961), 360 & 384

**Chemical Corps**(CC). A branch of US Army having primary responsibility for chemical warfare matters
*Refs:* 1)Anon, "Chemical Corps Reference Handbook", FM **3-8**(1955) 2)Glossary of Ord (1959), 67 3)Anon, "Chemical Service Units", FM **3-85**(1960)

**Chemical Cotton.** See under Chemical Cellulose

**Chemical Destruction of Explosives.** These methods rely upon chem reactions, which to be completed require time and full contact of the expl with the reagent, usually in soln. Chem methods should not be used in attempts to destroy expls in large quantities or when any of the expl items are enclosed or pressed into components such as detonators. Chem destruction methods are suitable for use in labs for quantities of expls not greater than ca 25g

In Ref 1 are described recommended chemical destruction methods for BkPdr, LA, MF & NG. The method described for BkPdr is the same as given in this Vol under Black Powder,p B177-R, and methods for destruction of LA are in Ref 2. Destruction of MF will be described under Fulminates and of NG under Glycerin,Nitro
*Refs:* 1)Anon, "Ordnance Safety Manual", **ORDM 7-224**, C3, Paragraph 302(1954) 2)PATR **2700**; Vol 1(1960),pp A551 & A573-A575

**Chemical Efficiency of Mortar** can be calcd from the equation: $E = (F \times W \times R)/M$, where E = efficiency; F = maximum rate of fire in rounds per minute; W = wt of shell filler(HE) in pounds; R = max range of mortar in yds; and M = wt of mortar, exclusive of accessories, spare parts and tools

For example, Amer 81mm Infantry Mortar has E = 48, while Amer 4.2in(106.7mm) Chemical Mortar has E = 254(See also table on p 72 of Ref)
*Ref:* A.M.Prentiss, ArmyOrd **29**, 71-3(1945)

**Chemical Energy Ammunition.** Ammo(such as HEAP or HEAT) intended to penetrate armor or other resistant targets by chem energy rather than kinetic energy as in conventional AP ammo
*Ref:* Glossary of Ord(1959), 69

**Chemical Factors in Propellant Ignition.** See M.A.Cook & F.A.Olson, AIChE **1**, 391-400(1955)

**Chemical Fire Starters.** Devices intended for starting fires under adverse climatic conditions, such as in wet jungles or on snow-covered terrain. The M1 fire starter is a cylindrical NC container 1.25" in diam by 3.25" in length filled with 0.8oz of kerosene thickened to a gel and provided with an ignition device, consisting of a match-head attached to a disk which covers the filling. A scratcher is attached inside a metal cap which covers the match head of the fire starter. The cap is fastened to the container with adhesive tape(Ref, pp 51-4 & Fig 30). A smaller fire starter, M2, is designed to be carried in a pocket of the Air Force survial kit for use by downed AF crew in starting fires under adverse climatic conditions. This device is a rectangular NC container, 0.5 x 0.5 x 3", contg 0.2oz of thickened kerosene and provided with an igniter which consists of a match-head mixture with a pull-type scratcher wire(Ref, pp 54-5 & Fig 31)
*Ref:* Anon, "Ground Chemical Munitions", TM **3-300**(1956), 51-5

**Chemical Flame Throwers.** See Flame Throwers

**Chemical Fuels for Rockets.** Discussion on their composition, energy and exhaust speeds is given by A.Stettbacher in Explosivst **1956**, 25-33

**Chemical Grenades.** General term for any grenade(hand or rifle) charged with a chemical

agent used for casualty, harassing, incendiary or screening(smoke) purposes. There are two types of chemical grenades: a)*Burning* type which ruptures the grenade body and releases the chem filling by a burning action (Ref 1, 355 & 357-8; Ref 2,pp 104-5 & Ref 5) and b)*Bursting* type which ruptures the grenade body and releases the chem filling by bursting of a small chge of HE(such as Tetryl) contained in a narrow tube placed in the center of chem filling(Ref 1,p 362; Ref 2,pp 106-9 and Ref 5)

Several types of chemical grenades used by the US Armed Forces during WWII are listed in Refs 1,2,3,4,6 & 7. In Ref 8, which lists grenades used as late as 1961, there are no chemical hand grenades and only the following three rifle grenades: a)Grenade, Rifle, Smoke, WP, filled with 8.48oz of white phosphorous(considered to be obsolete) b)Grenade, Rifle, Smoke, Colored, M22 & M22A2 and c)Grenade, Rifle, Smoke, Colored, M23 & M23A1. Fillers in grenades b) & c) weigh 6.40oz

(See also Chemical Candles)

*Refs:* 1)Ohart(1946), 355, 357-9 & 362; Fig 203 on p 357 2)Anon, "Ammunition General" TM **9-1900**(1956), 104-9; Fig 3 on p 15; Fig 68 on p 104; Fig 72 on p 109) 2a)Anon, "Ground Chemical Munitions", TM **3-300** (1956), 27-50(Chemical hand grenades) 3)Anon, "Grenade, Hand and Rifle, Smoke, WP, M 34", Dept of the Army Technical Bulletin TB **3-300-5**(1958) 4)Anon, "Grenade, Hand, Irritant, CN-DM, M6A1", TB **3-300-4** (1959) 5)Glossary of Ord(1959), 138 6)Anon, "Grenade, Hand, Tear, CS, M7A1", TB **57** (1960) 7)Anon, "Grenade, Hand, Tear, CS, M7A2", TB **86**(1961) 8)Anon, "Ammunition Complete Round Charts", Book III, PicArsn, Dover, NJ, Sheet 20(Grenades) 9)US Specifications-not found

**Chemical Ground Ammunition.** Title of the Department of the Army Technical Manual TM **3-300**(1956)

**Chemical Gun, Howitzer & Recoilless Rifle Shells.** Artillery projectiles filled with one or several chemical compds designed to produce either casualties(such as CWA's), fires(such as incendiaries) or to screen certain areas from view(such as smoke-producing compns). Shells contg smoke compns used for signalling purposes are usually classified as pyrotechnic items. Chemical shells were developed during WWI and used then to a great extent, especially by the Germans

The type of shell used during WWI consisted of a thin metallic container filled with a chemical(solid or liquid) and provided with a fuze and a booster larger than that in HE shells of corresponding caliber. The rupture of casing and scattering of chem filling were accomplished on bursting of the booster(or and auxiliary booster). As all of the bursting chge was located in one part of the shell, scattering of chem contents was not uniform and some undesirable fragmentation (instead of just rupture of casing) took place

For these reasons, a new type of chem shell was developed at PicArsn sometime after WWI. In the improved type of shell, a long thin metallic tube(such as of Al), filled with a booster type HE(such as Tetryl) was attached to the booster. As this tube, called *burster*, extends thruout the length of the shell, a better rupturing effect and more uniform scattering of chem filling can be obtained than with the older type. Very little effect is produced by fragments of new type of chem shell since the bursting chge is just sufficient to crack the shell and scatter the chemical filling. In firing chem shells it is important that they burst before entering the ground in order that the chemical be spread instead of being concentrated in and near the shell crater(Refs 1, 2 & 3)

Various types of chem artillery shells used during WWII are described in Ref 4

The following currently used US chem gun, howitzer and recoilless rifle shells are listed in Ref 5:

a)Inc(Incendiary) and HE-Inc shells for 20mm Guns(Sheet 1)
b)WP Smoke for 57mm Gun M1(obsolete)(Sheet 4)
c)WP Smoke for 57mm Recoilless Rifles M18 & M18A1(Sheet 4)
d)WP Smoke for 75mm Guns(obsolete)(Sheet 6)
e)WP Smoke for 75mm Recoilless Rifle M20 (Sheet 7)
f)WP Smoke for 75mm Howitzers M1A1 & M3 (obsolete)(Sheet 8)
g)WP Smoke for 76mm Guns M32 & M48(Sheet 9)
h)WP Smoke for 76mm Guns M1A1C & M1A2 (obsolete)(Sheet 10)

i)WP Smoke for 90mm Guns M36, M41 & M54 (two types of shells)(Sheet 14)
j)WP Smoke, HD Gas(Persistent), GB Gas (Nonpersistent) and HC Smoke for 105mm Howitzers M2A1, M2A2 and M49(Sheets 16 & 17)
k)WP Smoke for 105mm Recoilless Rifle M27 (Sheet 18)
l)WP Smoke with Tracer for 120mm Guns M1A3 & M58(Sheet 21)
m)HD Gas(Persistent), H Gas(Persistent), GB Gas(Nonpersistent) and WP Smoke Shells (three different types) for 155mm Howitzers M1, M1A1 and M45(Sheet 22)
n)WP Smoke(two types of shells), HD Gas and GB Gas for 155mm Guns M2, M2A1 and M46(Sheet 23)
(See also Ref 6)
*Note:* For meaning of US CW(chemical warfare) symbols, such as WP, HD, etc, see under CHEMICAL AGENTS
(This section was reviewed by A.B.Schilling)
*Refs:* 1)Hayes(1938), 562-3 2)Anon, "Ammunition Inspection Guide", TM **9-1904** (1944), 17 & 128 3)Ohart(1946), 106 & 120 4)Anon, "Artillery Ammunition", TM **9-1901** (1950), 17,19-20,122-3,131-2,144-6,150,152, 159,166-9,185-6,195-8,216-17,222-5 & 240 5)Anon, "Ammunition Complete Round Chart", Book II, "Artillery Ammunition", PicArsn(1961) 6)Anon, "Assembly of Explosive Components", TB(Technical Bulletin) **9-1300-203-1**(1961) (Description of: 105mm Howitzer shell contg nonpersistent gas GB; 155mm Gun shell contg GB or persistent gas VX; 8 inch Howitzer shell contg either GB or VX gas)(Formula of VX, is classified)

**Chemical Hand Grenades.** See under Chemical Grenades

**Chemical Howitzer Shells.** See under Chemical Gun, Howitzer & Recoilless Rifle Shells

**Chemical Ignition.** Various chemical igniters are discussed by A.Stettbacher in NC **9**, 75-7, 100-1, & 138-41(1938)

**Chemical Ignition and Flame Throwers.** This subject is discussed by E.C.Kirkpatrick, in OSRD Rept **3507**(1944)

**Chemical Incendiary Devices.** When it is required to destroy by fire, materials(such as classified papers) or equipment(such as filing cabinets) which should be prevented from falling into undesirable hands, devices consisting of sheet-metal boxes filled with incendiary mixts, such as thermites can be used. Several of these devices are described in the Ref
*Ref:* Anon, "Ground Chemical Munitions", TM **3-300**(1956), 55-63

**Chemical Industry; Case Histories of Accidents in the.** This subject is discussed in the book published by Manufacturing Chemists Assoc, Inc, Washington 9, DC, Vol I(1962)

**"Chemical Kinetics and Chain Reactions".** Title of the book by N.N.Semenoff, Clarendon Press, Oxford(1935)

**Chemical Land Mines.** These mines are usually employed to disperse persistent war gases from fixed locations. In most cases they are located together with HE mines in mine fields. None of these mines is described in Refs 1,2 & 4 and only one type, the 1 gallon, in Ref 4. This mine consists of a rectangular can, 1.1gal capacity contg 1gal of liquid such as HD or H(see under CHEMICAL AGENTS) and provided with a burster chge & a firing device(electric or nonelectric). The mine is buried slightly below the surface of the ground and can be actuated either by pressure of a person stepping on it or by pull (or sheer) of a trip wire. This action causes the burster to explode, which is followed by rupture of the mine casing and release of chemical agent designed to harass or poison enemy personnel

Another US land mine, the 2 gallon, M23, described in Ref 4,is filled with persistent gas VX(formula of gas is classified)

The use of chemical land mines is now very limited and one of the reasons for this is the possibility of shifting winds blowing chem agents into positions of friendly troops
(This section was reviewed by A.B.Schilling of PicArsn)
*Refs:* 1)Anon, "Ammunition General", TM **9-1900**(1956)-not found 2)Anon, "Land Mines", TM **9-1940**(1956)-not found 3)Anon, "Ground Chemical Munitions", TM **3-300** (1956), 64-8 4)Anon, "Ammunition Complete Round Chart", Book III, PicArsn, Dover, NJ (1961), Sheet 21-not found 5)Anon, "Mine,

Gas, Persistent, VX, 2 Gallon, M23, TB CML **76**(1962)

**Chemical Mines.** See Chemical Land Mines

**Chemical Mortar & Chemical Mortar Shells.** Chemical mortar is a weapon(see under CANNONS) designed to fire shells contg toxic or harassing chemicals, substances producing screening smokes, or incendiaries. These shells are called *chemical mortar shells.* The term "chemical mortar" is somewhat obsolete, because current US mortars are capable of firing, besides expl types of shells, also chem types(Refs 1,2 & 4)

The most important of these mortars is the 4.2inch Mortar which is a rifled, muzzle -loading weapon(Refs 1,1a,3 & 5) capable of firing a chemical shell equipped with a rotating unit which includes a cup-shaped annular disc of soft metal, of the same diam as the shell body. Under the action of propInt gases, transmitted thru a pressure plate, the flange of the disc is forced outward into the rifling, performing the same function as the rotating band of gun- or howitzer shells. The propelling charge consists of NH(non-hygroscopic) smokeless propInt, in the form of thin discs. The chge is ignited by means of an igniter cartridge(Refs 1,2 & 4)

The following chemical type shells have been used in 4.2-in Mortar M30: WP Smoke, PWP Smoke, H Gas, HT Gas, CK Gas, CG Gas and FS Gas(now obsolete(See Ref 6, Sheet 20)

*Note:* For meanings of symbols such as WP, PWP etc, see under CHEMICAL AGENTS

There are also TNT shells and Ill (Illuminating) Shells for 4.2in Mortar M30 but they do not belong to chemical ammunition

A smaller, current US mortar, the 60mm, is a smooth-bore, muzzle-loading weapon (Refs 3 & 5) capable of firing(besides TNT and Ill shells), one type of WP shell(Ref 6, sheet 5). Another US smooth-bore, muzzle -loading mortar, the 81mm(Refs 3 & 5), can fire(besides TNT, Comp B, Ill and Inert shells), three types of WP smoke and two types of FS shells(Ref 6, Sheets 11 & 12)

During WWII the US Army used a small (2 inch caliber) mortar(mounted on a table) provided with a cylindrical shell 6in long, enlarged at the head to act as a bourrelet and filled with a smoke mixt which was ignited by the propellent gases. This mortar was similar to the British 2 inch Bomb Thrower (Ref 2,p 120)

*Refs:* 1)Hayes(1938), 568 1a)Anon, "Mortar, Chemical, 4.2 inch", TM **3-320**(1945) 2) Ohart(1946), 120 & 191 3)Anon, "Artillery Matériel and Associated Equipment", TM **9-2300**(1949), 78-83 4)Anon, "Artillery Ammunition", TM **9-1901**(1950), 122-30, 166-70 & 201-6 5)Anon, "Principles of Artillery Weapons", TM **9-3305-1**(1956), 160-3 6)Anon, "Ammunition Complete Round Chart", Book II, "Artillery Ammunition", PicArsn, Dover, NJ(1961), Sheets 5,11,12 & 20

**Chemical Mortar, 4.2 inch; Propellant for.** The following compn was developed and tested at PicArsn during WWII: NC(13.25% N) 53.5, NG 43.0, diethylphthalate 3.0 & DPhA 0.5%, with methylcellulose 0.03%, added. It was in the shape of squares 2.2" x 2.2" and 0.013" thick, with one perforation 1.35" in diam. Its thermal stability, as judged by 65.5° Surveillance Test and 120° & 135° Heat Tests, was satisfactory

*Ref:* W.H.Rinkenbach, PATR **1359**(1943), Table VI

**Chemical Mortar Shells.** See under Chemical Mortars & Chemical Mortar Shells

**Chemical Munitions.** In a broad sense, any and all supplies and equipment required to conduct offensive or defensive war by means of chemical agents. This includes chemical weapons, chemical ammunition, transport and fuel, but excludes personnel and supplies and equipment for purposes other than for direct military operations. In a restricted sense, the term means *chemical ordnance,* which includes chemical military matériel, such as combat weapons with ammunition and equipment for their use, vehicles, repair tools and machinery (See also Chemical Ammunition)

*Refs:* 1)Anon, "Ground Chemical Munitions", TM **3-300**(1956) 2)Glossary of Ord(1959), 192(Munitions) and 202(Ordnance)

**Chemical Munitions: Destruction, Handling, Storing and Shipping.** See Anon, "Ordnance Safety Manual", ORDM **7-224**(1951), paragraphs 2907 to 2937 and Anon,

"Ground Chemical Munitions", TM **3-300** (1956), 84-6

**Chemical Ordnance.** See under Chemical Munitions

**Chemical Pots or Smoke Pots.** Portable containers, usually cylindrical in shape, filled with a chemical smoke-producing agent. They may be subdivided into "burning" and "generator" types. The former type is usually filled with a mixt consisting of HC 47, ZnO 47 & granulated Al 6%; when ignited it burns with evoln of dense smoke. The latter type usually contains "fog oil" which is one of the petroleum oils SGF1 or SGF2; when heated by burning fuel, the "fog oil" vaporizes producing dense smoke

The following US smoke pots are described in the Ref: a)Pot, Smoke HC, M1 b)Pot, Smoke, 30-lb, M5 c)Pot, Smoke, Floating HC, M4A2 d)Pot, Smoke SGF2, An-M7 and e)Pot, Smoke SGF2, Mk 5, Mod 2
*Ref:* Anon, "Ground Chemical Munitions", TM **3-300**(1956), 6-26

**Chemical Priming.** Under the title: "Chemische Kurz- und Langzeitzündung", Stettbacher(Ref) described various delay action primers activated by chemical means. Most of these primers were used in sabotage items
*Ref:* Stettbacher(1948), 130-2

**Chemical Problems of Space Flight** are discussed by F.Hecht in the "3rd InternAstronautCorgr, Stuttgart, Ger, Oct 1952 [CA **49**, 11286(1955)]. The paper includes a review of new proplnts, ceramic & high-temperature materials, plastics, chem purification techniques, gas analysis, atm research and other problems related to space flight

**Chemical Projectiles.** See Chemical Bombs, Chemical Grenades, Chemical Rockets and Chemical Shells

**Chemical Propellants.** Under this term, Bellinger et al describe several liquid rocket proplnts which were investigated at the Army Chemical Center, Edgewood Arsenal, Maryland
*Refs:* 1)F.Bellinger et al, IEC **38**, 160-9 (1946)(The system hydrogen peroxide -permanganate was found to be suitable for launching the JB-2 flying bomb, also known as "buzz" bomb) 2)Ibid, IEC **38**, 310-20 (1946)(Corrosion and stability studies of hydrogen peroxide-permanganate systems) 3)Ibid, IEC **38**, 627-30(1946)(Analytical studies and characteristics of the system hydrogen peroxide-permanganate) 4)Ibid, IEC **40**, 1320-31(1948) [Discussion on possibility of using MNMe(mononitromethane) in liq proplnts for launching "buzz" bombs. The great disadvantage of MNMe is its extreme sensitivity to mechanical action]

**Chemical Pulp.** Pulp prepd by a chem process, as distinguished from "mechanical" pulp which is prepd by grinding
*Ref:* Chambers's Technical Dictionary Macmillan, NY(1954), 155

**Chemical Recoilless Rifle Shells.** See under Chemical Gun, Howitzer and Recoilless Rifle Shells

**Chemical Rifle Grenades.** See under Chemical Grenades

**Chemical Rocket Engine.** A rocket engine that operates on chem proplnts rather than on other energy sources. Chem rocket engines may be operated by liquid or solid proplnts
*Ref:* RocketEncycl(1959), 87-8

**Chemical Rocket Propulsion and Combustion Research".** Title of the book by S.S.Penner, published by Gordon & Breach, NY(1962)

**Chemical Rockets.** Rockets equipped with chemical warheads. These heads consist of thin-walled casings loaded with casualty or harassing gas or smoke. They may be adopted for point fuzes or base fuzes and have a burster extending well along the axis of the head from the fuze seat(Ref 2,p 9)(See also Ref 1,pp 9 & 332)

Following chemical ground type rockets are described in Ref 2: 2.36-in Rockets, Smoke, WP: M10A4; -M10A2 and -M10A1(pp 41-2). 3.5-in Rocket, Smoke, WP, T127E2 (p 48); 4.5-in Rockets(Navy)(High Capacity, Smoke FS, and Smoke WP)(pp 53-4); 7.2-in Rockets, Gas: CG, M25(T21) and CK, M27 (T52),pp 69-70. Only one chemical aircraft rocket is listed in Ref 2. It is 3.5-in Rocket, Smoke FS, Mk7 Modifications. Its velocity is 1140fps(p 118). Two persistent gas types of

rockets are described in Ref 3 and two smoke, WP, rockets; 2.36-in, M10A2 and 3.5-in, M30 are described in Ref 4
*Refs:* 1)Ohart(1946), 9 & 232) 2)Anon, "Rockets", TM **9-1940**(1950) 3)Anon, "Rocket, Gas, Persistent, CB, 115mm and Rocket, Gas, Persistent, VX, 115mm, M55", TB **73**(1961) 4)Anon, "Ammunition Complete Round Chart", Book III, PicArsn, Dover, NJ (1961), Sheet No 28

**Chemical Safety.** See under Safety in Chemical and Ordnance Plants

**Chemical Shells.** See Chemical Gun & Howitzer Shells, Chemical Mortar Shells, Chemical Recoilless Rifle Shells and Chemical Rockets

**Chemical Sprays.** Liquid sprays from aerial release devices designed to cause harassing or casualty effects(war gases), screening (smoke compns), or fires(incendiary compns)
*Ref:* Glossary of Ord(1959), 69

**Chemical Stability of Explosives and Propellants; Determination of.** See Stability of Explosives and Propellants. Determination of

**Chemical Stabilizer.** A substance added to a proplnt or expl mixts to reduce chem decompn during storage. To these belong Acardites(see Vol 1,p A7-R of this Encyclopedia), Centralite, DPhA(diphenylamine), etc

**Chemical Tests for Explosives and Propellants.** See under individual expls and proplnts

**"Chemical Tests for New Explosives".** Title of NDRC, Div B report by R.McGill, OSRD **787**(PBL No 30778)(1942)

**Chemical Warfare(CW).** The tactics and technique of using chemical agents in offensive action, or of employing defensive measures against such actions
(See also Chemical, Biological and Radiological Warfare)
*Ref:* Glossary of Ord(1959), 69

**Chemical Warfare Agents(CWA).** See CHEMICAL AGENTS and under Chemical, Biological and Radiological Warfare

**Chemical Wood Pulp.** Pulp obtained from wood by the sulfite, sulfate or soda process(See Wood Cellulose under CELLULOSE)

**Chemische Fabrik Dynamites.** This German Co patented, as NG absorbents, the substances prepd by the method of Parks(based on discovery of Bielefeldt). These absorbents were prepd by reacting sulfur monochloride($S_2Cl_2$) with a vegetable oil(process similar to vulcanization of rubber by the action of $S_2Cl_2$ on $CS_2$). The resulting mass, although as elastic and pliant as rubber, absorbed NG just as well as kieselguhr. It was claimed that dynamites with this "dope" were comparatively insensitive; they could be mixed with PA, TNT, MF & other expls and used for loading shells
*Ref:* Daniel(1902), 134

**Chemisorption.** It is the chemical phenomenon associated with absorption(Vol 1,p A105-L). In chemical adsorption(chemisorption) definite chemical bonds are produced betw the atoms & molecules on the surface of solid absorbents and the molecules or atoms of "adsorbates". Chemisorption is usually accompained by an enormous evolution of heat(of the order of tens of thousands kcal per mole) and is very difficult to reverse. As an example of chemisorption, may be cited adsorption of oxygen on incandescent tungsten or of hydrogen & nitrogen by tungsten even in the cold
*Refs:* 1)Kirk & Othmer I(1947), 217ff; and 1st Suppl(1957), 144 2)S.J.Gregg, "Surface Chemistry of Solids", Reinhold, NY(1951), Chemisorption, 245-70 3)W.E.Garner, Edit, "Chemisorption", Butterworths, London & Academic Press, NY(1957)

**Chemocol.** See Chemecol

**Cherenkov(Čerenkov)Radiation** is the very faint emission of a bluish light from transparent substances(such as glass, water, etc) developed in the vicinity of strong radioactive sources. This phenomenon, first observed by M-me Curie ca 1910 and later by other workers in the field of radioactivity, was not understood until P.A.Cherenkov explained it after conducting exhaustive studies in 1934-1938, incl. He also developed an instrument("Cherenkov counter") which became useful for research

in high energy fields. Investigations on Cherenkov radiation have been resumed since 1940 by other workers, and an instrument more versatile than Cherenkov counter, called "photomultiplier", was developed

The complete mathematical theory and numerous applications of Cherenkov radiation in various fields, such as optics, nuclear physics, high frequency radio techniques, astrophysics and cosmic rays are discussed in the Ref

*Ref:* J.V.Jelley, "Čerenkov Radiation and Its Applications", published for the United Kingdom Atomic Energy Authority, Pergamon Press, NY (1958)

**Cherokee Ordnance Works.** Ordnance Corps field installation located at Danville, Pennsylvania

**Chiaraviglio & Corbino Stability Test.** Expls are heated at relatively low temps and the pressure of gases formed on decompn of expl is recorded by a very sensitive manometer(Ref 2). A detailed description of this is given in Ref 1

*Refs:* 1)D.Chiaraviglio & O.M.Corbino, AttiAccadLinceiRend **24**, (5a), 120(1915) 2)Reilly(1938), 88

**Chicago Ordnance Plant.** Ordnance Corps ammo plant, located in Chicago 35, Illinois

*Ref:* OrdTech Term(1962), 70

**Chidite.** A mine blasting expl, based on Amm Perchlorate, used extensively in Canada ca 1910-20. It was considered preferable to dynamites in cold climates because, unlike NG, it was not adversely affected by freezing. The market for this compn was dissipated ca 1920 due to the competitive appearance of other non-freezing blasting explosives

*Ref:* G.F.Smith, Analyst **80**, 19(1955)

**Chikkaen**(Navy) or **Chikka Namari**(Army). Japan for Lead Azide

**Chile Saltpeter.** Same as Sodium Nitrate. See under Nitrates

**Chilworth Special Powder or Chilworth Smokeless Sporting Powder.** See Amide Powder, Vol 1,p A168-R and PATR 2510 (1958),p Ger 4

**China Clay.** The product obtd by leaching weathered deposits of granitic rocks, so that quartz & mica portions are removed (Ref 1). For example, when Feldspar weathers, the first product is Cornish stone; this next becomes china clay rock from which the china clay is obtd. The purest china clay is known as *kaolin* and consists mainly of hydrated aluminum silicate(Ref 2)

It is used as an ingredient of some Brit Permitted Explosives, such as Polar Ajax & Polar Dynobel No 2; and in some US HE & pyrotechnic compns

*Refs:* 1)Hackh's(1944), 190 2)J.H.White, "A Reference Book of Chemistry", Univ of LondPress, London(1960), 212

**Chishokianin.** Japan name for 2,3,4,6-Tetranitroaniline. See Vol 1,p A411-L

## CHITIN

*Chitin,* $(C_8H_{13}NO_5)_n$; mw $(203.19)_n$, N 6.89%, wh solid(when pure); insol in w & in solvs which dissolve cellulose; decomp to glucosamine(also called chitosamine) & acetic acid when boiled with concd HCl; nitrous acid converts it to *chitose,* a form of sugar; treatment with strong alkalies gives AcOH & *chitosan,* a split-product of chitin (Refs 4 & 7)

It is a naturally occurring horny substance which forms the framework of invertibrates(such as crabs, lobsters & other mollusca), and is the animal analog of cellulose of plants. Chitin is considered a polymer, constg of more than 100 units of anhydro-N-acetylglucosamine, a deriv of D-glucose. It possesses the same degree of polymerization as wood cellulose and has the characteristics of polysaccharides

Due to the fact that chitin contains one acetyl group for each $C_6$ unit, it can be deacetylated to a solid prod useful in the prepn of expls. Also because it contains OH groups, it may be converted into useful esters(Ref 7)

*Refs:* 1)Beil-not found 2)K.H.Meyer & H. Wehrli, Helv **20**, 353-62(1937) & CA **31**, 5807 (1937)(Chemical comparison of chitin with cellulose) 3)G.A.Hill & L.Kelley, "Organic Chemistry", Blakiston, Philadelphia(1944), 191 4)Hackh's(1944), 191 5)J.T.Marsh &

F.C.Wood, "An Introduction to the Chemistry of Cellulose", Chapman & Hall, (1945), 106-7 6)Karrer(1950), 349 7)Kirk & Othmer **11**(1953), 10 & 2nd Supplement (1960), 222-27 8)Fieser & Fieser(1956), 388-89

**Nitrated Chitin or Chitin Nitrate,** $[C_6H_7O_2(ONO_2)_2.NH.CO.CH_3]_n$; mw $(293.19)_n$, N 14.33%(found 7.5% nitrate N); wh fibrous flakes, ignites ca 163° & burns vigorously; thermally stable by Abel Test; insol in most solvs; partially sol in formic acid(from which it is repptd by w); sol in concd $H_2SO_4$ or HCl(from which it is not repptd by w); various org solvs such as benz, tetralin, aniline, nitrobenz, phenol, pyridine & furfural cause it to swell; it is completely denitrated by NaSH in 3 hrs at 16°(Ref 3)

This compd was first obtd by nitrating chitin with concd $HNO_3$(d 1.50); the chitin dissolved after 1-2hrs at RT and soln was poured into a large amt of cold w(Ref 3). The product contained 7.5% nitrate N, indicating that only 1.5 instead of 2(OH) groups had been esterified. Earlier, Fürth & Scholl(Ref 2) treated chitin with fuming $HNO_3$ and obtd two products, one of them insol in ordinary solvs while the other was sol in alc, acet, ethyl acetate, acetic acid but insol in eth. It was claimed that both products were nitro-esters of chitin but no further investigations were made. Shoruigin & Hait(Ref 3) claimed the 1st prod(insol) was chitin nitrate while the 2nd prod consisted of oxidized products of decompd chitin. Meyer & Wehrli(Ref 4) also prepd nitrochitin as well as other derivs of chitin. According to M & W, the additive derivs of chitin with mineral acids are not homogeneous compds but mixts of polyglucosamines

*Refs:* 1)Beil-not found 2)O.vonFürth & E. Scholl, BeitrChemPhysiol **10**, 188-98(1907) & CA **1**, 3020(1907) 3)P.P.Shoruigin(or Schorigin) & E.Hait, Ber **67**, 1712-14(1934) & CA **29**, 473(1935) 4)K.H.Meyer & H.Wehrli, Helv **20**, 353-62(1937) & CA **31**, 5807(1937)

**Chitin, Deacetylated.** A product which has lost ca 85% of the N-acetyl groups of natural chitin; small creamy to lt-tan flakes; sol in dil aq solns of AcOH(repptd by neutralization); sol in w or alc; sl sol in 98-100% $HNO_3$ (0.30 gm dissolved in 20g $HNO_3$ at 30°); when its soln in $HNO_3$ was poured into ice water, a wh flocculent ppt was obtd which exploded when heated rapidly; insol in perchloric acid(Ref 3)

Deacetylated chitin can be prepd by the method of Rigby(Ref 3) which consists of heating at 110° for 4hrs, shrimp, lobster or crab shells(previoulsy washed by successive treatments with boiling 1% NaOH soln, 5% HCl soln & $Na_2CO_3$ soln contg some soap) with 40% NaOH soln. This method was checked & confirmed by Meyer & Wehrli(Ref 4) and Wolfrom et al(Refs 5 & 6). It is claimed that this treatment does not degrade the product in regard to polymerization

The *Perchlorate salt,* of 85% deacetylated chitin, a cream-colored, granular, free-flowing expl product(with an acid content of 96% theoretical, calcd as perchloric acid), was prepd by Wolfrom et al(Ref 6) by a method considered an extension of the method described by Hofmann et al(Ref 2). This salt, sol in 100% $HNO_3$, detonated(leaving considerable carbon residue) when heated confined over an open flame

*Refs:* 1)Beil-not found 2)K.A.Hofmann et al, Ber **43**, 1080(1910) 3)G.W.Rigby, USP 2040879(1936) & CA **30**, 4598(1936) 4)K. Meyer & H.Wehrli, Helv **20**, 353(1937) & CA **31**, 5807(1937) 5)M.L.Wolfrom et al, JACS **65**, 2084(1943) 6)M.L.Wolfrom et al, Ohio State Univ Final Rept, Project 459, Columbus, Ohio(Jan 1953)pp 1,3 & 34

**Nitrated Deacetylated Chitin.** A wh flocculent ppt contg 11.6 to 11.9% nitrate N(as detd by DuPont nitrometer; obtd by Wolfrom et al(Ref 3) by nitrating deacetylated chitin with 100% $HNO_3$. The nitrated product represented the combined nitrate salt & nitrate ester of deacetylated chitin. This substance contd one nitric acid salt unit per anhydro-D-glucosamine unit and 1.60-1.65 nitrate ester unit per anhydro-D-glucosamine & anhydro -N-acetyl-D-glucosamine units. Attempts to nitrate deacetylated chitin by means of nitrogen pentoxide, in a non-aqueous medium & in the presence of sodium fluoride, by the method of Caesar(Ref 2) were unsuccessful mainly because of occlusion of NaF in the nitrated products(Ref 3)

The nitrated deacetylated chitin was insol in w or acet but sol in a 1:1 mixt of the two. On heating in a test tube over an open flame, it decompd with a puff leaving a considerable amt of carbon residue

Its *Perchlorate salt,* contg 11.4% total N,

7.1% nitrate N & 26.1% perchloric acid, was prepd by Wolfrom et al(Ref 3) by nitrating, with 100% $HNO_3$, the perchlorate of deacetylated chitin(See above). The salt so prepd was insol in either acet or w but completely sol in 6:1 or 1:1 acetone-w. The material decompd with a burst of flame, leaving no residue, when heated over an open flame

*Refs:* 1)Beil-not found 2)C.V.Caesar, USP 2400287(1946) & CA **40**, 4487(1946); JACS **68**, 372(1946) 3)M.L.Wolfrom et al, Ohio State Univ Final Rept, Project 459, Columbus, Ohio(Jan 1953)

**Chloramine or Chloramide**(Monochloramine), $NH_2Cl$ ; mw 51.48, N 27.20%; col oil with a strong ammoniacal odor; fr p -66°, very unstable as it is decompd with expl violence by heat or agitation, sol in water. It can be prepd by the action of ammonia on Na hypochlorite or dil hypochlorous acid

Chloramine was widely used in the treatment of water supplies between 1930-44 but many water plants have abandoned this treatment to-day. It has bactericidal props, but against many organisms its action is much weaker than free chlorine. This compd can react, under alkaline condition, with excess ammonia to form hydrazine

*Refs:* 1)Gmelin, SystNr **6**(1927), 418ff 2) Mellor **8**(1928), 604 3)Davis(1943), 427 4) Hackh's(1944), 192 5)Kirk & Othmer **3**(1949), 665 6)E.Colton & M.M.Jones, JChemEduc **32**, 485-87(1955)(A review of the chemistry of monochloramine) 7)CondChemDict(1961), 252

**o- & m-Chloranilinium Pentazidodicuprates,** $C_6H_4ClNH_3[Cu_2(N_3)_5]$ ; exp compds which darken at 80° and explode at 210-13°. See Cupric Azide Complexes, & Ref 16 in Vol 1,p A533-R

## CHLORATES

**Chlorates.** Compounds formed from chloric acid($HClO_3$), by combination of the monovalent radical $-ClO_3$ & a metal, hydrogen or other radical, are called chlorates. The chlorate salts are crystalline & some are deliquescent; they are decompd by heat with evolution of oxygen; sol in water; and are powerful oxidg agents. The principal toxic effects are the production of methemoglobin in the blood & destruction of red blood corpuscles

A very large number of chlorates are known and they may be divided into inorg & org chlorates. Inorg chlorates of alk or alkaline earth metals are prepd either by action of chlorine on hot alkali or by electroytic oxidn of the chloride ion. For the prepn of org chlorates, such as pyridine chlorate, a pyridine base is treated with an aq soln of $HClO_3$. Kirk & Othmer(Ref 8), Gmelin(Ref 3) & others describe various methods of prepg chlorates. See also under various chlorate compds described below

Chlorates mixed with combustible materials may form expl compns. For example, an expln can occur if a chlorate is mixed with org matter, charcoal or sulfur and the mixt is struck with a hammer or heated. In the expl industry, chlorates are used as oxidg agents in combination with MF, phosphorus, antimony sulfide & other combustible substances for primer cap compns. They are also used in pyrotechnic compns for flares & aerial bombs, and as a component of permissible expls. Chlorates, as well as perchlorates, are used extensively in the manuf of Cheddites(qv)

*Refs:* 1)R.Escales,"Chloratsprengstoffe," Viet & Co, Leipzig(1910), 1-62(Historical description of chlorates & chlorate expls) 2)Mellor **2**(1922), 296ff 3)Gmelin, SystNr **6** (1927), 307-62 4)Ullmann **3** 2nd ed (1929), 278-307; **5**, 3rd ed (1954), 525-42 5)Thorpe **3**(1939), 66ff 6)Mellor(1939), 512 6a)I.F. Blinov, "Chlorate and Perchlorate Explosives," Oborongiz , Moscow(1941) 7)I.Kabik, US BurMines Info Circ **7340**(1945) & CA **41**, 4311 (1947)(Hazards from chlorates & perchlorates in mixts with reducing materials) 8)Kirk & Othmer **3**(1949), 707ff 9)Sax(1957), 459 10)T.A.Rodgers & C.J.Wassink, "Studies of Thermal Decomposition of Chlorates and Perchlorates at Constant Temperatures and Pressures", Univ of Ark Final Summary Rept (1958)(Dept of Army Contract No DA-23-072 -ORD-1049) 10a)R.G.Hall, USP 2841481 (1958) & CA **52**, 17716(1958)(Stable pyrotechnic compns are obtained by mixing a liq phenol-, urea-, or melamine-formaldehyde condensation product and a 120-mesh oxidizing material such as an Amm, alkali metal or alk-earth metal chlorate, perchlorate or nitrate or urea nitrate in a 1:1-3 ratio and polymerizing for 3mins at 80-100°) 11)F.A.Warren et al, "Chlorates and Perchlorates Their Manufacture, Properties and Uses", NAVORD Rept **7147**

(Vol 1)(1960)(Contract NOrd 18471) 12)F.A. Warren et al, "Chlorates and Perchlorates Their Characteristics and Uses", NAVORD Rept 7147(Vol 2)(1960)(Conf)(Not used as a source of info)

**Chlorates, Analytical Procedures.** Following are some tests for chlorate ion:

*A. Qualitative Tests:*

a)Testing by heating with $H_2SO_4$. Place a few mgs of solid material in a Pt crucible, add a few drops of concd $H_2SO_4$ and heat with a flame; an expln accompanied by evoln of yel fumes indicates a chlorate(Ref 5,p 262)

b)Spot test with $MnSO_4$ + $H_3PO_4$. This test described by Feigl(Ref 9) is applicable for testing expls. It is based on the formation of complex $Mn^{+++}$ ions when a chlorate is treated with $MnSO_4$ in a concd phosphoric acid soln:

$ClO_3^- + 6Mn^{++} + 12PO_4^{---} = 6Mn(PO_4)_2^{---} + Cl^- + 3H_2O$.

The resulting color is more or less violet depending on the chlorate content. Very pale colors may be intensified by adding a drop of an alc soln of diphenylcarbazide. Limit of sensitiveness is 0.00005mg

c)Color test by aniline. It is one of the oldest methods and depends on the formation of a blue coloration when a soln of aniline in concd $H_2SO_4$ is added to an aq soln of sample. Several modifications of the original method are known. Aniline sulfate may also be used for the quantitative detn of chlorates(Ref 1,pp 243-4; Ref 8, vol 2,pp 266-7)

d)Method of Denigès. Place in a small test tube 2 drops of test soln and add gradually, with stirring and cooling under tap w, 2ml of $H_2SO_4$. Then add without stirring 5drops of resorcinol reagent(prepd by dissolving 1g of resorcinol in 10drops of $H_2SO_4$) and swirl the tube gently while cooling it under tap w. Green color indicates a chlorate. If the color is too intense, dil the soln with w. Limit of sensitiviness is 0.00001g. Nitrites interfere giving blue color, but this can be overcome by using a modified procedure described by Gody(Ref 1,p 244)

e)Method of Lafitte. Add to test soln a few drops of aq aniline(1:40) and then HCl(d 1.18), twice as much by vol. A red-violet color developes immediately but this changes to dark blue and then to green. As little as 0.0006g of chlorate can be detected in a satd soln of K nitrate, but many oxidizing agents (such as chlorine, hypochlorite, etc) interfere (Ref 1,pp 243-4)(See also Ref 8, vol 2,p 267-8)

f)Other colorimetric and spot tests. See Refs 1,4,8 & 9

g)Testing of samples suspected to contain chlorates, chlorides or perchlorates. Acidify the aq soln of sample slightly with nitric acid and add an excess of Aq nitrate soln. Formation of ppt of AgCl indicates the presence of a chloride. Boil the slurry and filter off the coagulated ppt. To the clear filtrate add a few mls of 40% formaldehyde and boil to reduce the chlorate to chloride. Add an excess of Ag nitrate and allow to stand on a steam bath for 1hr, while the mixt is protected from light. Remove ppt of AgCl by filtration and evap the filtrate(in a dish) to dryness and the disappearance of nitric acid odor. Cool the dish and transfer the ppt, using a small amt of w, to small pt crucible. Dry the contents by heating and fill the crucible near the top with anhydrous Na carbonate or with Amm chloride. Fuse the mass, cool it and dissolve in dil nitric acid. Add an excess of Aq nitrate soln and, if ppt of AgCl forms, the presence(in original sample) of perchlorates is indicated (Ref 3,pp 14-15)

*Note:* Other reducing agents than formaldehydes (such as Zn in an acid, sulfur dioxide or ferrous sulfate) may be used(Refs 5,6,7 & 11)

*B. Quantitative Tests*

a)Reduction with formaldehyde. This test, essentially the same as qualitative test (g) was used at the USBurMines explosives laboratory at Bruceton, Pa. It is an accurate method, but rather time consuming. A detailed description of the test is given in Ref 3,pp 63-4(See also Ref 5,p 1677)

b)Reduction with sulfur dioxide. This test described by Gody(Ref 1,p 245) and by Storm (Ref 3,pp 62-3), has been used at the BurMines. For this procedure, treat an aliquot part of the w extract of an explosive(preferably contg not more than about 0.50g of chlorate) with a current of sulfur dioxide (such as provided by a small cylinder of liq $SO_2$) and regulate the current by means of a valve in such a manner that no excessive rise in temp of the reaction vessel is observed. Continue this opn until a strong odor of $SO_2$ persists in the soln after stopping the current and blowing across the surface of the liquid. After complete saturation with $SO_2$, boil the

liq to remove any traces of $SO_2$ and then add a few mls of $H_2O_2$ soln, which oxidizes the last traces of $SO_2$ to $SO_3$. Acidify the soln with a few drops of $HNO_3$ and det the chloride (resulting from the reduction of the chlorate) by pptn with Ag nitrate soln and weighing as AgCl

Complete removal of $SO_2$ from the soln is necessary in order to prevent reduction of the Ag nitrate

(See also Ref 5,p 274)

c)Reduction with ferrous sulfate. See Ref 5,pp 274 & 1677; Ref 6, Vol 2,pp 390 & 565; Ref 11,pp 607-9 and Ref 15,pp 313 & 571

d)Ferrous ammonium sulfate. See Ref 5,p 2160

e)Reduction with zinc in acetic acid. See Ref 5,pp 275,276 & 1677; Ref 6, Vol 2, p 391

f)Reduction with Devarda's alloy. See Ref 6, Vol 2,p 391

g)Reduction by ignition with ammonium chloride. See Ref 6, vol 2,p 391

h)Reduction with hyrochloric acid. See Ref 6, Vol 2,pp 599 & 601

i)Reduction with bromide in the presence of hydrochloric acid. See Ref 15,pp 361-2

j)Reduction with iodide in the presence of hydrochloric acid. See Ref 15,p 361-2

k)Titration with standard mercurous nitrate solution. See Ref 15,p 399

The following procedure described in Ref 6, Vol 2,p 390, is accdg to Ref 11, applicable for analysis of the pure chlorates of Ag, Al, Amm, Ba, Ca, Cd, Cs, Cu, Fe, K, Li, Mg, Na, Ni, Pb, Rb and Zn

*Procedure:* Dissolve a 0.3g sample in 100ml of w, add 50ml of 10% soln of $FeSO_4.7H_2O$, heat with const stirring to boiling and maintain for 15mins. Cool, add sufficient amt of $HNO_3$ to dissolve the basic ferric salt,and then an excess of $AgNO_3$ soln. After allowing the ppt of AgCl to settle in a dark place, filter thru a sintered glass crucible, wash with w and dry, first at 100° and then at 130°, to const wt. One gram of AgCl corresponds to 0.8550g $KClO_3$

Accdg to Ref 11,p 608, this analysis is not applicable to chlorates of Co, Au, Cr, Mn and probably Hg. This is because they offer possibility of cationic interference in the reduction step. This interference can be overcome by reducing chlorate to chloride by ignition with $Na_2CO_3$ or $NH_4Cl$ followed by detn of resulting chloride by pptn with $AgNO_3$

A volumetric method for simultaneous detn of chlorate and perchlorate in presence of each other was recently described by DeSousa(Ref 12). In this method one portion of the sample, together with 12 times its wt of $NH_4Cl$, is heated in a Pt dish, covered with a ribbed watch glass, for 1-2hrs, just below the fusion pt of residual chlorides(in order to avoid damage to Pt dish). This operation is repeated with addnl amt of $NH_4Cl$. The chlorates and perchlorates are reduced to chlorides. The second portion of sample is boiled, while stirring, for 15mins with 10% $FeSO_4$ soln in oder to reduce chlorates, leaving perchlorates unchanged. Then the 1st portion is dissolved (after cooling) in w acidified with $HNO_3$ and an excess of $AgNO_3$ soln is added to ppt chlorides as AgCl. At the same time the 2nd portion is cooled, acidified with $HNO_3$(until the basic ferric salts are redissolved) and treated with an excess of $AgNO_3$ as above. After filtering each portion separately thru Gooches and washing the AgCl ppts, first with 0.1% $AgNO_3$ and then with 1% $HNO_3$, they are transferred, without drying, to 1 liter beakers, each contg sufficient amt of ammonical 0.1M potassium nickel cyanide soln to satisfy the reaction: $2AgCl + K_2Ni(CN)_4 = 2KAg(CN)_2 + NiCl_2$

The 0.1M $K_2Ni(CN)_4$ soln is prepd by titrating 1 mole KCN dissolved in ca 500ml of w contg ammonia, with 0.1M $NiSO_4$ soln until murexide indicator(satd soln of Amm purpurate, made fresh daily) changes from yel to purple. Then the soln is diluted to 1 liter

As soon as contents of beakers are completely dissolved, the solns are diluted to ca 500ml and titrated, in presence of murexide indicator, with 0.1M disodium ethylene-diaminetetraacetate(EDTA) to chge of color from yel to purple. Each ml of 0.100M EDTA corresponds to 16.691mg $ClO_3^-$ and 19.891mg $ClO_4^-$

(See also Refs 2,4,10 and under individual chlorates)

*Refs:* 1)Gody(1907), 243-4(Colorimetric tests for chlorates) 2)Escales, Chloratspr(1910), 45-8(Qualitative); 48-51(Quantitative); 51-2 (Detn of impurities in chlorates); 72-4(Tests for chlorates in BkPdr) 3)C.G.Storm, "The Analysis of Permissible Explosives", US BurMinesBull **94**(1916), 14-16 & 62-4 4) Gmelin, SystNr **6**(1927), 351-62 5)Scott & Furman(1939), 262,274-6,1677 & 2160 6) Treadwell & Hall **2**(1942), 390-1, 565,599 & 601 7)Kast-Metz(1944), 464 8)Welcher **1**

(1947), 144, 181 & 382(Detns with β-naphthol, resorcinol or formaldehyde); **2**(1947), 266-7, 322,354,421 & 441(Detns with aniline, benzidine β-naphthylamine, β-naphthylphenylamine & phenyldihydrobenzoacridine); **3**(1947), 39 & 445(Detns with pyridine & diphenylcarbazide); **4**(1948), 187,270,508 & 520(Detns with thiourea, brucine, strychnine, indigo carmine & methylene blue) 9)Feigl **1**(1954), 274-5 & 300(Spot tests); **2**(1956), 484(Spot test for chlorates in expls) 10)E.A.Burns, "Spectrometric Determination of Chlorate Impurities in Ammonium Perchlorate", CalTechProgress Rept **30-12**(1959), Contract No NASW-6 11)F.A.Francis et al, "Chlorates and Perchlorates", NAVORD Rept **7147**(Vol 1) (1960), 607-10 12)A.D. de Sousa, Chemist Analyst **49**, No 1, 18(1960)("Determination of Chlorate and Perchlorate in Presence of Each Other") 13)H.Laub, ZAnalChem **173**, 208-10(1960) & CA **54**, 16254(1960)(Sepn of various anions, including $ClO_3^-$, by paper chromatography) 14)I.I.M.Elbeih & M.A.Abou-Elnaga, AnalChimActa **23**, 30-5(1960) & CA **54**, 18195(1960)(A new scheme of analysis for the common anions, including $ClO_3^-$ based on paper chromatography) 15)Vogel, InorgAnalysis(1961), 313,361-2, 399 & 571

**Chlorates, Destruction of.** One of the simplest methods for destruction of a chlorate is to treat the sample with concd HCl, followed by evaporation to dryness
*Ref:* Scott & Furman(1939), 907

### List of Chlorate Compounds

**Aluminum Chlorate,** $Al(ClO_3)_3$. The anhyd salt could not be prepd. Attempts to prep it by heating the hydrates always led to explns. This compd exists as hexa- and ennea-hydrates: *Hexahydrate,* $Al(ClO_3)_3.6H_2O$; mw 385.44, col hygr rhombohedral crysts, mp dec or expl >100°; can be prepd by treating a hot soln of Ba or Ca chlorate with a soln of $Al_2(SO_4)_3$. After filtering the ppt of Ba or Ca sulfate, the filtrate must be evapd by heating in a desiccator contg concd $H_2SO_4$. If the evapn is done in the cold, the *Enneahydrate,* $Al(ClO_3)_3.9H_2O$, is obtd. It is sol in w, eventually forming a basic salt on standing; also sol in alc & in dil HCl. According to Dobrosserdoff(Ref 1), when a hydrated Al chlorate is slowly heated, it decomposes & explodes forming chlorine dioxide, $ClO_2$; and when heated rapidly, it dec without expln, forming chlorine, basic perchlorate & oxide

Al chlorates not only act as oxidg agents, but also due to w of crystallization, as cooling agents in proplnts
*Refs:* 1)D.K.Dobrosserdoff, ZhRusFiz-Khim-Obshch **36**, 468(1904) 2)Mellor **2**(1922), 353 3)Gmelin, SystNr **6**(1927), 338 & 342 4) Ullmann **3**(1929), 297 5)Anon, US War Dept Tech Manual TM **3-250**(1940), 36, "Storage and Shipment of Dangerous Chemicals" 6) CondChemDict(1950), 30(Not listed in 1961 edit) 7)Sidgwick, Chem Elems **1**(1950), 428 8)Sax(1957), 261 9)F.A.Warren et al, "Chlorates and Perchlorates", NAVORD Rept **7147**(Vol 1) (1960), 139

**Ammonium Chlorate,** $NH_4ClO_3$; mw 101.50, N 13.80%; wh crysts, mp sublimes & explodes 70-100°(depending on rate of heating & sample size); accdg to Kast(Ref 7,p 208), Salvadori reported mp 60°; sol in w; heating aq soln above 75° causes spontaneous decompn; sol in AcOH & aq alc; nearly insol in abs alc. Was first prepd by Gay-Lussac in 1815 from aq $HClO_3$ & $NH_4OH$ or $(NH_4)_2CO_3$. It can be prepd also by treating a soln of Amm silicofluoride with $KClO_3$ or by the reaction of $(NH_4)_2CO_3$ & $Ca(ClO_3)_2$ or $Ba(ClO_3)_2$ (Refs 3 & 5). Gelhaar(Ref 1) prepd the salt by neutralization of aq $HClO_3$ with $NH_3$ and evapn of the w; he thoroughly examined its props(See below under Explosive Properties). Fairbrother(Ref 4) reptd that a cold satd soln of $NH_4ClO_3$ appears to undergo no decompn when kept indefinitely; if any solid phase is present decompn occurs in a few days

Ammonium chlorate is an expl compd. It is highly dangerous and can explode when shocked or exposed to heat(Ref 13). Potjewijd (Ref 10) reported that a drum of weed killer (100 kg) exploded with violence on the premises of a hospital. It was suspected that $NH_4Cl$ had been added to the $KClO_3$ resulting in formation of $NH_4ClO_3$
*Explosive Properties* were detd by Gelhaar (Ref 1), Naoúm & Aufschläger(Ref 6), Kast (Ref 7) etc. *Brisance:* by Kast's Formula, $19.8 \times 10^6$(TNT $86.1 \times 10^6$) and by Cu Crusher Test 1.5mm at d 0.9(TNT 3.6mm at d 1.59) (Ref 7) *Detonation Velocity:* 3300m/sec at d 0.9(Ref 7) *Explosion Temperature:* expl at 94° in 7mins at 100° in 3.5mins & 107°

in 2mins(Ref 1); 102°(Ref 5); when heated in a sealed capillary tube, it expl with noise (Ref 7) *Friction Sensitivity* - decrepitates when rubbed in a porcelain dish(Ref 7) *Gas Volume:* 827.8 l/kg(Refs 1 & 7) *Heat of Expln* (Qe): 441cal/g(Ref 1); 468cal/g(Ref 6) & 459cal/g(Ref 7) *Heat of Formation*(Qf); 64kcal/mol or 620cal/g(Ref 7) *Ignition:* can be ignited by gas flame or BkPdr fuse(Ref 46) *Impact Sensitivity* with 2kg wt 15cm(Ref 1) & 20cm(Ref 7) *Initiation Sensitivity* - See Sensitivity to Initiation ' *Power*, by Trauzl Test,254cc(Ref 1); 240cc(Ref 6) and 245cc (Ref 7) *Sensitivity to Initiation*-can be detonated by a std blasting cap,but it is preferred to use cap & booster(such as PA)(Ref 7) *Stability in Storage* is unsatisfactory; when stored at RT it decomp slowly leaving AN as a residue and not the chloride or perchlorate as would be expected(Ref 8); when stored at above RT or in closed containers, ignition or spontaneous expln may occur(Refs 2 & 9)
*Uses:* Because of its unsatisfactory stability and high sensitivity to mechanical action, it cannot be recommended for use in military expl or pyrotechnic compns. Nevertheless, the Japanese Navy used it during WWII in an expl of unknown name which consisted of $NH_4ClO_3$ 51.5, $Ba(NO_3)_2$ 34.5, woodpulp 5.0 and oil + TNN 8.2parts(Ref 12). Another example is the expl patented by Billwiller(Ref 11): mixt of $NH_4ClO_3$ with naphthalene, paraffin wax and/or lubricating oil; it could be initiated, when confined, with thermite. Accdg to Ref 5, $NH_4ClO_3$ was used in some Ger detonators and in blasting expls contg liquid TNT
*Refs:* 1)J.Gelhaar SS **11**, 166-7(1916) 2) Clover(1918), 280 3)Mellor **2**(1922), 338 4)F.Fairbrother JACS **44**, 2419-22(1922) & CA **17**, 37(1923) 5)C.A.Taylor & Wm.H. Rinkenbach, US BurMinesBull **219**(1923), 36-7 6)F.Naoúm & R.Aufschläger SS **19**, 123(1924) 7)H.Kast, SS **21**, 208-9(1926) & **22**, 8(1927) 8)Gmelin, Syst Nr **6**(1927), 337 & 342 9)Ullmann **3**(1929), 297 10)T. Potjewijd, PharmWeekblad **72**, 68-9(1935) & CA **29**, 1985(1935) 11)J.Billwiller, FrP 862323(1941) & CA **42**, 9180(1948) 12) Anon, "Handbook of Japanese Explosive Ordnance", OPNAV **30-3M**(1945), 32 13)Sax (1957), 275 14)F.A.Warren et al, "Chlorates and Perchlorates", NAVORD Rept **7147** (Vol 1)(1960), 139-40

**Ammonium Chlorate, Analytical Procedures.** Chlorate ion may be detd by methods outlined under Chlorates, Analytical Procedures, while ammonium ion may be detd as outlined under Ammonium Chromate, Analytical Procedures (under CHROMATES)

There is no US Specification for Ammonium Chlorate

Amm chlorate, usually present in tech Amm perchlorate, is an undesirable impurity if the material is intended for use in expl or pyrotechnic compns. This is because Amm chlorate lowers deflagration temp and impairs the stability of Amm perchlorate. For these reasons, only small amts of chlorates are usually tolerated, such as 0.02%(calcd as $NH_4ClO_3$) in Amm perchlorate intended for use in US rocket proplnts, tracer ammo and flame throwers(Ref2,pp 2 & 6)

As only traces of Amm chlorate are present in Amm perchlorate, a colorimetric test can be used, such as by means of brucine -sulfuric acid reagent(Ref 1) or by ortho -tolidine reagent(Ref 2)
*Refs:* 1)C.Eger, AnalChem **27**, 1199-1200 (1955) & CA **49**, 13835(1955) 2)US Military Specification **MIL-A-192A**(1)(1961), 4 (Ammonium Perchlorate)

**Anilinochlorates.** See Vol 1,p A406-R of this Encyclopedia, under Salts of Aniline with Inorganic Acids

**Barium Chlorate,** $Ba(ClO_3)_2$, mw 304.27; col crysts, mp 414°(dec); begins to evolve oxygen at 300°; decrepitates or decomp violently when heated rapidly; $Q_f$ 181kcal/mol. Can be prepd by dehydrating the monohydrate. *Monohydrate,* $Ba(ClO_3)_2.H_2O$; mw 322.29; col, non-hygro nonoclinic crysts; mp begins to loose $H_2O$ at 120°, evolves O at 300°; d 3.179; $n_D$ 1.562 at 20°; sol in w [22.8g of $Ba(ClO_3)_2$ in 100g of w at 0°, 37 at 20°, 77.5 at 60° & 126.4g at 100°] (Ref 5b); sl sol in alc or eth. It was prepd in 1802 by R.Chenevix and in 1815 by L.N.Vauquelin by passing chlorine into w in which Ba hydroxide or carbonate was suspended. Present methods of prepn include electrolysis of hot $BaCl_2$, saturation of a hot aq soln of $Ba(OH)_2$ with chlorine, or reaction of $BaCl_2$ & Na chlorate(Refs 1,2,3,4,5 & 8)

Ba chlorate is a very powerful oxidg agent and is dangerous when mixed with org

compds, especially hydrocarbons
*Uses:* Ba chlorate has been used in some primer and igniter compns(Ref 15,p 255), but more often in pyrotechnic compns. In these mixts, Ba chlorate not only supplies the oxygen required for combustion but also imparts to the flame the characteristic green color of Ba compds. Most of its uses were for green light pyrotechnic compns used for signalling purposes, such as: a)Rocket green signal compn: Ba chlorate 55.5, Ba nitrate 33.3 & orange shellac 11.2%(Ref 1,p 159) b)Green rifle light and green Véry light compn: Ba chlorate 90 & orange shellac 10%(Ref 1,p 159) c)Green position light compn: Ba chlorate 23.2, Ba nitrate 59.0, K chlorate 6.3, orange shellac 10.5 & stearin 1%(Ref 1,p 159) d)Green light compn: Ba chlorate 40, Ba nitrate 50 & shellac 10%(Ref 7) e)Ital green light: Ba chlorate 70, shellac 17 & lactose 13%(Ref 9a, p 211) f)Ger green star signal: Ba chlorate 64, K chlorate 18 & shellac 18%(Ref 9a,p 211 & Ref 12a,p Ger 154) f)French green star: Ba chlorate 85, carbon 3 & shellac 12%(Ref 9a,p 227) g)Fr green star with parachute: Ba chlorate 90, castor oil(or vaselin) 2 &accorides gum 8% (Ref 9a,p 227) h)Ger green star: Ba chlorate 86, accroides gum 11 & carbon(fine pdr) 3% (Ref 9a,p 229) i)Rus green light: Ba chlorate 81 & accroides gum 19%(Ref 10a,pp 118 & 195) j)Rus green lights: Ba chlorate 85 & shellac 15%; Ba chlorate 89 & iditol 11% and Ba chlorate 63 Ba nitrate 25 & iditol 12% (Ref 10a,p 194) k)Ger green signal light: Ba chlorate 81.1, S 10.8, charcoal 2.7 & calomel 5.4%(Ref 12a,p Ger 154)

Ba chlorate is not used in current US expl or pyrotechnic compns and there is no US Specification. It was used, however, during and sometime after WWI and the Specification requirements were, accdg to Faber(Ref 1,pp 163-4), as follows: Color-white, or with only very sl yel tinge; odor - none; purity as $Ba(ClO_3)_2.H_2O$ 99.5%; acidity - none; insol matter - trace; moisture, max 0.2%; bromates, calcd as Br, max 0.01%; Na salts, calcd as $Na_2O$, max 0.25%; K salts, calcd as $K_2O$, max 0.25%; granulation: 100% thru 80-mesh screen and 60% thru 100-mesh. Kast-Metz(Ref 5b,p 514), gives similar requirements, but in addn: chlorides & sulfates -traces and Fe & Ca salts absent
*Refs:* 1)Faber, Pyrotechnics, **3**(1919), 151-64 2)Mellor **2**(1922), 344 3)Gmelin, SystNr **6** (1927), 337 & 339 4)Ullmann **3**(1929), 297 5)Mellor(1939), 514 5a)Davis(1943), 70,72, 86 & 119 5b)Kast-Metz(1944), 513-14 5c) Weingart, Pyrotechnics(1947), 133 & 146 6)B.P.Seipel, ChemAnal **38**, 81-3(1949) & CA **44**, 2400(1950)(Laboratory prepn of Ba chlorate) 7)R.F.Barrow & E.F.Caldin, ProcPhysSoc(London), **32B**, 32-9(1949) & CA **44**, 939(1950) 8)Kirk & Othmer, **3** (1949), 715 9)CondChemDict(1950), 82 9a)Izzo, Pirotecnía(1950), 211-12, 227 & 229 10)Sidgwick, ChemElms **1**(1950), 258 10a)Shidlovskii(1954), 22-3, 27-8, 67, 118, 149 & 194-5 11)P.Remy-Genneté & G. Durand, BullFr **1955**, 1059-60 & CA **50**, 1419(1956)(Soly of Ba chlorate in alc-w mixts) 12)Sax(1957), 331 12a)PATR **2510** (1958),p Ger 154 13)F.A.Warren et al, "Chlorates and Perchlorates", NAVORD Rept **7147**(Vol 1)(1960), 140 14)CondChem-Dict(1961), 125-6 15)Ellern, Pyrotechnics 1961), 56, 97, 99 & 255

**Barium Chlorate, Analytical Procedures.** Chlorate ion may be detected and detd as described under Chlorates, Analytical procedures while Ba ion can be detd as described in Refs 2,3 & 5

Faber(Ref 1) describes the following quantitative tests: moisture, $Ba(ClO_3)_2.H_2O$ content; hypochlorites, bromates, acidity, insoluble matter, Ca salts & Na salts, but he advises to make preliminarily the following qualitative tests for the purpose of detg the purity of the salt in a general way, in order to indicate the method of procedure: a)Flame test - by means of a Pt wire moistened with concd HCl, dipped in the powdered salt and heated in the flame of Bunsen burner and b)Chloride test - by adding a few drops of Ag nitrate soln to a soln of Ba chlorate. Turbidity in the soln will indicate the presence of traces of chloride

Kast-Metz(Ref 4) described methods of analysis of green-light pyrotechnic compns contg besides Ba chlorate, the following substances: shellac(or rosin accroides gum), with or without K chlorate, calomel, lactose, dextrin and powdered carbon or Mg
*Refs:* 1)Faber, Pyrotechnics **3**(1919), 160-64 2)Scott & Furman(1939), 117,127 & 129 3)Treadwell & Hall, Vols 1 & 2(1942) 4)Kast-Metz(1944), 530-31 5)Vogel, InorgAnalysis

(1961), 554

**Benzylamine Chlorate,** $C_6H_5.CH_2.NH_2.HClO_3$ ; mw 191.59, N 7.31%; yel hygr pltlts, mp 110.5°; sol in w or alc; insol in eth or benz; was prepd by mixing aq chloric acid with an excess of benzylamine. Its expl props were not investigated
*Refs:* 1)Beil **12,** (446) 2)R.L.Datta & J.K. Choudhury, JACS **38,** 1082(1916)

**Benzylethylamine Chlorate,** $C_6H_5.CH_2.NH.C_2H_5.HClO_3$; mw 219.67, N 6.37%; col crysts, mp 81.5, burns explosively in a flame; sol in hot w or alc; insol in eth or benz; was prepd by heating benzylethylamine with a sl excess of aq chloric acid
*Refs:* 1)Beil **12,** (448) 2)R.L.Datta & J.K. Choudhury, JACS **38,** 1082(1916)

**Benzylmethylamine Chlorate,** $C_6H_5.CH_2.NH.CH_3.HClO_3$; mw 205.64, N 6.81%; col crysts, mp 59.6°, burns explosively in a flame; sol in w or alc; insol in eth or benz; was prepd by heating benzylmethylamine with a sl excess of aq chloric acid
*Refs:* 1)Beil **12**(448) 2)R.L.Datta & J.K. Choudhury, JACS **38,** 1082(1916)

**Cadmium Chlorate,** $Cd(ClO_3)_2$; mw 279.33, col crysts; can be prepd by prolonged heating of the dihydrate at approx 65°
*Dihydrate,* $Cd(ClO_3)_2.2H_2O$; mw 315.36; col delq prismatic crysts, mp 80°(dec), d 2.28 at 18°; very sol in w or alc; sl sol in acet; can be prepd by saturating a hot slurry of $Cd(OH)_2$ with chlorine, or by the action of $Ba(ClO_3)_2$ on $CdSO_4$. Both salts are power oxidg agents which will explode by heat or shock

Cadmium chlorate reacts with ammonia to form *Tetramminecadmium(II) Chlorate,* $[Cd(NH_3)_4](ClO_3)_2$; and *Hexammine cadmium (II) Chlorate,* $[Cd(NH_3)_6](ClO_3)_2$, both of which are expl metal ammines. See Vol 1, Table A,p A277
*Refs:* 1)A.Meusser, Ber **35,** 1420(1902) 2) Mellor **2**(1922), 350 3)Gmelin, SystNr **6**(1927), 341 4)CondChemDict(1950), 125 5)Sidgwick, ChemElems **1**(1950), 277 6)Sax(1957), 418

**Calcium Chlorate,** $Ca(ClO_3)_2$; mw 207.00, wh delq crysts; can be obtd by heating the dihydrate above 76°. *Dihydrate,* $Ca(ClO_3)_2.2H_2O$; mw 243.03, wh delq monoclinic crysts, mp-looses $H_2O$ above 100°, further heating causes decompn; d 2.711; v sol in w; sol in alc or acet; can be prepd either by saturating a hot aq suspension of slaked lime with chlorine, or by electrolysis of $CaCl_2$. An interesting lab method of prepg the pure compd is given by Ehret(Ref 5). It is an oxidg agent which can be used in pyrotechnics when an orange-colored light is desired

The *Tetra-* and *Hexa-hydrates* have been reported(Ref 7)
*Refs:* 1)Escales, Chloratspr(1910), 13 2) Mellor **2**(1922), 344 3)Gmelin, Syst Nr **6**(1927), 341 4)Ullmann **3**(1929), 297 5)W.F.Ehret, JACS **54**, 3127, 3130(1932) 6)Thorpe **2**(1938), 214 7)Sidgwick, ChemElems **1**(1950), 257 8)Sax(1957), 425 9)F.A.Warren et al, "Chlorates and Perchlorates", NAVORD Rept **7147**(Vol 1)(1960), 140

**Chromous Chlorate,** $Cr(ClO_3)_2$; its aq soln was prepd in 1877 by L.Storck & W. de Coninck by treating chrome alum with barium chlorate; can also be prepd by treating chromic sulfate with potassium chlorate. The soln is a strong oxidg agent. According to Sidgwick (Ref 3), the solid salt has been made, but it is very unstable
*Refs:* 1)Mellor **2**(1922), 357 2)Ulmann **3** (1929), 297 3)Sidgwick, ChemElems **2**(1950), 1013

**Cobaltous Chlorate,** $Co(ClO_3)_2$, very unstable salt; can be prepd by carefully heating the dihydrate. *Dihydrate,* $Co(ClO_3)_2.2H_2O$, pale red powd; can be obtd by keeping the tetrahydrate over $P_2O_5$
*Tetrahydrate,* $Co(ClO_3)_2.4H_2O$; mw 297.92, dk-red crysts; can be obtd by maintaining the hexahydrate above 18.6°
*Hexahydrate,* $Co(ClO_3)_2.6H_2O$; mw 333.95, dk-red cubic delq crysts, mp 61°, bp dec at 100°, d 1.92; very sol in w or alc; was obtd by Wächter in 1843 by treating an aq soln of cobaltous sulfate with barium chlorate, filtering the ppt of $BaSO_4$, and evapg the filtrate to dryness over $H_2SO_4$ below 18.5°

When treated with ammonia, cobalt chlorates form the following ammines which are expl: *Tetramminecobalt(III) Chlorate,* $[Co(NH_3)_4](ClO_3)_2$; *Aquopentamminecobalt(III) Chlorate Monohydrate,* $[Co(NH_3)_5.H_2O](ClO_3)_2.H_2O$; and *Hexamminecobalt(III) Chlorate Monohydrate,* $[Co(NH_3)_6](ClO_3)_3$.-

$H_2O$(See Vol 1; Table B,p A278; Table C,p A279; and Table D,p A280)
*Refs:* 1)Mellor **2**(1922), 360 2)Ullmann **3** (1929), 298 3)Sidgwick, ChemElems **2**(1950), 1383 4)Sax(1957), 494 5)Gmelin, Syst Nr **58**(1961), 581

**Cupric Chlorate,** $Cu(ClO_3)_2$; the anhydrous salt has not been prepd. *Hexahydrate,* $Cu(ClO_3)_2.6H_2O$; mw 338.55; grn cubic delq crysts, mp 65°, bp dec 100°; v sol in w; sol in alc or acet; was prepd in soln by L.N. Vauquelin, in 1815, by dissolving copper hydroxide or carbonate in aq chloric acid. In 1843 A.Wächter prepd the solid salt by evapg, in vacuum, the filtrate obtd by mixing aq solns of $Ba(ClO_3)_2$ & $CuSO_4$. Some investigators(Ref 1) have claimed that the hexahydrate is really the *tetrahydrate*

A *basic salt* of compn $Cu(ClO_3)_2.3Cu(OH)_2$ is also known(Ref 1)

When copper chlorate is heated with ammonia, the following ammino-compds, which are expl, are formed: *Tetrammine-copper(II) Chlorate,* $[Cu(NH_3)_4](ClO_3)_2$; and *Hexamminecopper(II) Chlorate,* $[Cu(NH_3)_6](ClO_3)_2$(See Vol 1, Table E,p A281).Copper chlorate primary ammine complexes of the general formula $Cu(ClO_3)_2NH_2X$(where X=$CH_3$, $C_2H_5$, $C_3H_7$ or $C_6H_5$) were prepd by Amiel(Ref 3) by saturating a concd soln of $Cu(ClO_3)_2$ with the corresponding ammine. The resulting complexes are dk-blue cryst expl compds, some of which are unstable even at RT
*Refs:* 1)Mellor **2**(1922), 342 2)Ullmann **3** (1929), 298 3)J.Amiel, CR **199**, 51-3(1934) & CA **28**, 5361(1934) 4)Sidgwick, ChemElems **1**(1950), 155 5)Sax(1957), 516

**Diethylphenylbenzylammonium Chlorate,** $N[(C_2H_5)_2C_6H_5.CH_2C_6H_6].ClO_3$; mw 323.81, N 4.33%; crysts, mp 77°, bp dec >125° with effervescence; sol in w or alc; was prepd by double decompn of $AgClO_3$ & diethylphenylbenzylammonium chloride. When left in air for long periods, this compd parially decomposes; and it burns with a flash in contact with a flame
*Refs:* 1)Beil **12**,(451) 2)R.L.Datta & J.K. Choudhury, JACS **38**, 1085(1916)

**Dimethylphenylbenzylammonium Chlorate,** $N[(CH_3)_2C_6H_5.CH_2C_6H_5)]ClO_3$; mw 295.76, N 4.74%; wh hygr crysts, mp dec at 137°; explodes when heated rapidly or in contact with concd $H_2SO_4$; sol in w or alc; was prepd by double decompn of dimethyl-phenylbenzylammonium bromide & $AgClO_3$ and evapn of soln over $H_2SO_4$. It slowly decomp to a gray mass when left at RT for several days
*Refs:* 1)Beil **12**,(450) 2)R.L.Datta & J.K. Choudhury, JACS **38**, 1085(1916)

**Ethylbenzylamine Chlorate.** See Benzyl-ethylamine Chlorate, above

**Ethylenediamine Dichlorate,** $H_2N.CH_2.CH_2.NH_2.2HClO_3$; mw 229.03, N 12.23%; col flat crysts(from w or alc), mp dec at 150°, burns with a flash in contact with a flame; sol in w or alc; was prepd by neutralizing an ethylene-diamine soln with chloric acid, and evapg the resulting soln on a w bath to crystn

This compd explodes violently, when dry, on heating or shock. It has been proposed for use, either alone or in mixts with MF, in primers & blasting caps(Ref 2)
*Refs:* 1)Beil **4**, (399) 2)A.Stähler, GerP 290999(1915) & CA **11**, 1549(1917) 3)R.L. Datta & J.K.Choudhury, JACS **38**, 1083(1916)

**Guanidine Chlorate,** $H_2N.C(:NH).NH_2.HClO_3$; mw 143.54, N 29.27; wh crysts, mp dec 148°, defgr on heating in a flame or in contact with concd $H_2SO_4$; was prepd by double decompn of guanidine sulfate & $Ba(ClO_3)_2$
*Refs:* 1)Beil **3**,(40) 2)R.L.Datta & J.K. Choudhury, JACS **38**, 1805(1916)

**Hydrazine Chlorate,** $H_2N.NH_2.HClO_3$; mw 116.66, N 24.20%; wh hygr crysts, mp 80°, explodes when heated above its mp; v sol in w, v sl sol in alc; insol in eth, benz or chlf; its alc sol is unstable. It was prepd by Salvadori(Ref 1) by neutralizing a dil soln of chloric acid with a dil soln of hydrazine hydrate, followed by evapg *in vacuo* over $H_2SO_4$

This compd explodes violently by percussion. Its expl power, according to Escales(Ref 2), is considerably greater than that of MF
*Refs:* 1)R.Salvadori, Gazz **37** II, 32(1907) & JCS **92**, 759(1907) 2)Escales, Chloratspr (1910), 198 3)ADL, PureExplsCompds, Part **1**(1947), 72

**Lead Chlorate(Normal),** $Pb(ClO_3)_2$; mw 374.12, wh hygr crysts, mp dec, d 3.89; can be obtd by prolonged heating of the mono-hydrate above 110°. *Monohydrate,* $Pb(ClO_3)_2.$-

$H_2O$, mw 392.14; wh monoclinic delq crysts, mp(looses $H_2O$ above 110°), bp(dec above 190° when heated slowly; explodes at 235° when heated rapidly); sol in w, nearly insol in alc. It was prepd in 1843 by Wächter by neutralizing a hot soln of chloric acid with lead oxide(PbO). W.K.Lewis prepd the salt by evapg to dryness equiv amts of PbO & $HClO_3$, dissolving the residue in a small amt of $HClO_3$ and addg abs alc which pptd the monohydrate(Ref 2)

Marin(Ref 1) observed that by dissolving Pb chlorate in hot glycerin, a deposit of wh crysts formed, after cooling the soln, which when separated & washed with alc constituted a very powerful detonating substance. It exploded violently when subjected to either heat or shock and was proposed for use in various primary compns for detonators, and in pyrotechnics

*Refs:* See below under Lead Chlorate(Basic)

**Lead Chlorate(Basic),** $Pb(ClO_3)_2.Pb(OH)_2$; mw 615.35, wh solid; can be prepd by treating 2 mols of lead oxide with 2 mols of hot concd chloric acid. There are also *Dibasic* and *Tribasic* salts

Marin(Ref 1) reacted basic lead chlorates with glycerin, tannin or concd solns of carbohydrates to obt various amor complexes. When di- or tri-basic salts were used, the resulting complexes were nearly insol in w. The most powerful & brisant of these expls were those prepd brom Pb chlorates & glycerin. These complexes exploded violently by heat or shock and were proposed for use in primer & initiating mixts

*Refs:* 1)A.J.Marin, FrP 478351(1915) & CA **10**, 2300(1916); USP 1206456(1916) & CA **11**, 211(1917) 2)Mellor **2**(1922), 356 3)Gmelin, Syst Nr **6**(1927), 339 4)Ullmann **3**(1929), 297 5)Sidgwick, ChemElems **1**(1950), 625 6)Sax (1957), 817 7)Ellern, Pyrotechnics(1961), 56

**Lithium Chlorate,** $LiClO_3$; mw 90.04; col delq rhmb ndls, mp 124-29°, dec at 270°; can be prepd by heating its hydrate to 90°. *Sesquihydrate,* $LiClO_3.\frac{1}{2}H_2O$; mw 99.40; col tetragonal crysts, mp 65°, bp(looses w at 90°); very sol in w(314g per 100g w) or in alc. It can be prepd by one of the following methods: a)electrolysis of lithium chloride soln b)interaction of $Ba(ClO_3)_2$ & $Li_2SO_4$ solns and c)by mixing aq solns of LiCl & $NaClO_3$, separating the pptd NaCl, and concg the resulting filtrate to obt $LiClO_3$

According to Kirk & Othmer(Ref 4), $LiClO_3$ has a limited use in pyrotechnics

The prepn of *Lithiumtetrammine Chlorate* is reported(Ref 1)

*Refs:* 1)Mellor **2**(1922), 326-29 2)Gmelin, SystNr **6**(1927), 341 3)Ullmann **3**(1929), 298 4)Kirk & Othmer **3**(1949), 715 5)Sax(1957), 831 6)F.A.Warren et al, "Chlorates and Perchlorates", NAVORD Rept **7147**(Vol 2)(1960), 140-1

**Magnesium Chlorate,** $Mg(ClO_3)_2$; mw 191.23. The anhyd salt has not been prepd. *Dihydrate,* $Mg(ClO_3)_2.2H_2O$, forms on drying the tetra- or hexa-hydrate at 65°. *Tetrahydrate,* $Mg(ClO_3)_2.4H_2O$, forms on drying the hexahydrate at 35°. *Hexahydrate,* $Mg(ClO_3)_2.6H_2O$, mw 299.33, wh delq crysts, mp 35°, dec at 120°, d 1.80 at 25°; very sol in w. In 1844, A.Wachter prepd the hexahydrate by treating $Ba(ClO_3)_2$ with the hexahydrate by treating $Ba(ClO_3)_2$ with $MgSO_4$ in aq soln, filtering the pptd $BaSO_4$ and evapg the filtrate over concd $H_2SO_4$ (Refs 2,3 & 4). According to Sidgwick(Ref 5), this compd is formed when chlorine is passed into cold w contg magnesium oxide in suspension

Magnesium chlorate was proposed by von Weldon as a starting material in the prepn of other chlorates, when it is desired to obt them in the pure state(Refs 2,3 & 4)

*Refs:* 1)K.A.Hofmann et al, Ber **47**, 1993 (1914) 2)Mellor **2**(1922), 349 3)Gmelin, SystNr **6**(1927), 341 4)Ullmann **3**(1929), 298 5)Sidgwick, ChemElems **1**(1950), 240 6)Sax (1957), 841 7)F.A.Warren et al, "Chlorates and Perchlorates", NAVORD Rept **7147**(Vol 1)(1960), 141

**Manganous Chlorate,** $Mn(ClO_3)_2$; mw 221.86. In 1843 A.Wächter(Ref 1) prepd a nearly colorless soln of manganous chlorate by treating $Ba(ClO_3)_2$ with manganous sulfate and filtering the ppt of $BaSO_4$. Evapn of the filtrate was successful up to a certain concn, then decompn took place and the soln turned red. Jahnsen(Ref 2) obtd a yel-brn ppt of *Manganous-amino-chlorate* by treating a cold soln of $Mn(ClO_3)_2$ with ammonia. This product was unstable and rapidly darkened by oxidn

*Refs:* 1)A.Wächter, JPraktChem **30**, 321(1843) 2)A.Jahnsen, "Über die Ammoniakate einige Schwermetallchlorate, -bromate, und -iodate", Dissertation, Zürich(1915) 3)Mellor **2**(1922), 359

**Mercuric Chlorate,** $Hg(ClO_3)_2$; mw 367.52, col delq needle-like crysts, mp dec, d 4.998; dec in contact with w; concd $H_2SO_4$ produces flashes of light. According to Mellor (Ref 1), the *basic salt,* $Hg(ClO_3)OH$ was first prepd in 1815 by L.N. Vauquelin by the action of chloric acid on HgO and subsequent evapn of the soln

*Refs:* See below under Mercurous Chlorate

**Mercurous Chlorate,** $HgClO_3$; mw 284.07, wh rhmb crysts, mp detonates ca 250°, d 6.409; sol in w, alc or acet ac. This salt was first prepd in 1815 by L.N.Vauquelin, in 1843 by A.Wächter, and in 1895 by I.Traube all by the action of chloric acid on $Hg_2O$(Ref 1). It can also be prepd by the action of K or Na chlorate on a soln of mercurous nitrate

It is an oxidg agent which explodes when heated to decompn, but in admixture with combustible materials, it explodes more violently than when alone

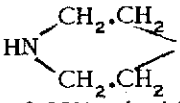
*Refs:* 1)Mellor **2**(1922), 351 2)Sax(1957), 857 & 865-66

**Methylbenzylamine Chlorate.** See Benzylmethylamine Chlorate, above

**Nickel Chlorate,** $Ni(ClO_3)_2$; mw 225.60. Anhyd salt has not been prepd. *Tetrahydrate,* $Ni(ClO_3)_2.4H_2O$; mw 261.62; is formed by heating the hexahydrate to 39°. *Hexahydrate,* $Ni(ClO_3)_2.6H_2O$; mw 333.70; dk-red crysts, mp(looses w at 39°), dec at 80°, d 2.07; sol in w. Was obtd by Wächter in 1843 by the double decompn of nickel sulfate & barium chlorate, followed by filtering the $BaSO_4$ and evapg the filtrate at RT over $H_2SO_4$ (Ref 2)

Ephraim & Jahnsen(Ref 1) prepd blue needle-like crysts of *Hexamminenickel(II) Chlorate,* $[Ni(NH_3)_6](ClO_3)_2$, mp 180°, dec explosively at 210°, d 1.52, by treating Ni chlorate with ammonia. See Vol 1, Table E,p A281

*Refs:* 1)F.Ephraim & A.Jahnsen, Ber **48,** 42(1915) 2)Mellor **2**(1922), 360 3)Ullmann **3**(1929), 299(erroneously lists as anhyd salt) 4)J.Amiel, CR **198,** 1033-35(1934) & CA **28,** 2633-34(1934)(Reactions of chlorates with sulfur, selenium, tellurium & org matter) 5)Sidgwick, ChemElems **2**(1950), 1437 6)Sax (1957), 934

**Piperazine Chlorate**(Diethylenediamine Chlorate),  $NH.2HClO_3$; mw 255.08, N 10.98%; wh shiny cryst plates, mp dec 98-100°, defgr in a flame; was prepd by double decompn of silver chlorate & piperazine hydrochloride

*Refs:* 1)Beil **23,**(4) 2)R.L.Datta & J.K. Choudhury, JACS **38,** 1083(1916)

**Potassium Chlorate,** $KClO_3$; mw 122.55; col, non-hygr monoclinic crysts, mp 368-70°, bp dec ca 400°, giving off oxygen; d 2.32, $Q_f$ -93.5kcal/mol; Heat Capacity 23.96 cal/deg/mol at 298°K; sol in w, alkalies or aq KCl; sl sol in glycerol or ethyleneglycol; nearly insol in abs alc or abs acet. Potassium chlorate is sl to moderately poisonous; the principal toxic effects are the production of methemoglobin and the destruction of red blood corpuscles. The probable lethal dose is 50-500mg/kg or betw one teaspoonful and one ounce for a 150-lb man

This salt was first isolated by C.L. Berthollet about 1786, hence the name "Salt of Berthollet". Two of the more important methods of prepg $KClO_3$ are: a)*Chemical(Indirect) Method* in which a hot satd soln of KCl is added, in sl excess, to a hot satd soln of $Ca(ClO_3)_2$; the soln is cooled to 0° and filtered, the ppt is washed with w and dried and b)*Electrolytic(Direct) Method* by electrolysis of KCl in a diaphragmless cell, using a cathode of steel & anode of graphite(Ref 19)

Potassium chlorate is a very powerful oxidg agent and, in admixture with combustible materials, it forms very powerful expls. According to Stettbacher(Ref 12), $KClO_3$ yields the most expl mixts with reducing materials, in comparison with other oxygen releasing salts; the most dangerous is *Armstrong's Mixture* contg red phosphorus & $KClO_3$(See Vol 1,p A485-R). Pérez Ara (Ref 16) reports that mixts of $KClO_3$ & sulfur are unstable and are readily exploded by heat or impact. The instability of sulfur-$KClO_3$ mixts is discussed in detail by Tanner(Ref 24). Mixts of $KClO_3$ & sugar are also very expl and may be detonated by flame,heat, impact or in contact with concd $H_2SO_4$

Accg to Marshall(Ref 4, vol 1, 378) Dupré showed that heat alone suffices to explode $KClO_3$ if it is applied with suddeness.

Under ordinary conditions, $KClO_3$(like $NH_4NO_3$), when not in contact with combustible matter, is not a dangerous material. However, in 1899 a large quantity exploded during a fire at the United Alkali Co, St Helens, England and did an enormous amt of damage. Other serious explns occurred at Manchester in 1908 and at Seaforth in 1910, both in England. Consequently, $KClO_3$ should be stored in a fire-proof bldg away from combustible materials, and it should be handled with great care

*Explosive Properties.* Kast showed(Ref 7a) that when K chlorate is heated in a sealed capillary a defgrn accompanied by weak noise takes place; when heated on a spatula or dropped on a red-hot iron surface an instant decompn with evoln of oxygen takes place. It is fairly insensitive to impact(one deton and one defgrn out of 6 tests were obtained with a 20kg wt dropped from the height of 16cm) and to friction(when tested by rubbing in a porcelin mortar). Its thermal stability proved to be very good even when heated to temps 170-80°. Attempts to ignite it by means of BkPdr fuse were unsuccessful and the tests for power(by Trauzl method), detonation velocity(by Dautriche method) and brisance (by copper cylinder crusher method) produced no measurable values(Ref 7a). Accdg to Blinov(Ref 13a), K or Na chlorates explode from a strong impact, if they are at temps above mp's

Some expl props of mixts of K chlorate with charcoal, woodmeal or Al power are given in Ref 7a

*Uses.* Berthollet tried to use $KClO_3$ in BkPdr as a replacement for saltpeter, but the results were disastrous(Ref 15). It took more than 100yrs to learn how to prep $KClO_3$ expls in such a manner as to be comparatively safe to handle. Large amts of $KClO_3$ have been used in HE's,(such as Cheddites, Kohlensprengstoffe, etc) in primer & igniter mixts (in combination with MF, LA, Sb sulfide, Pb thiocyanate wih or w/o abrasives), in matches, toy caps, pull-wire igniters, electric squibs, RR torpedoes, smokes, flares & signal lights (See also Refs 1,4,5,7,12,13a,14,15,16,17,18, 20a,21,22a,24a,26 & Addnl Refs). Some Ger primer compns of WWII are listed in Ref 23a,p Ger 136

When used in primer and igniter compns, $KClO_3$ increases their sensitivities tofriction and provides oxygen required for combustion of other ingredients. It has, however, the disadvantage to corrode firearms, because one of the products of its decompn is hot vapor of KCl, which is corrosive

Following are examples of US military primer and igniter compns contg K chlorate: a)*Primer Mix, US Army Standard*: K chlorate 33.4±2.0, Sb sulfide 33.3±2.0, LA 28.3 & carborundum 5.0±0.5%(Addnl Ref j, Method No 202 & Addnl Ref k) b)*Primer Mix No 70*: K chlorate plus gum 53.0±5.0, Pb thiocyanate 25.0±3.0, Sb sulfide 17.0±2.0 & TNT(Grade I) 5.0±0.5%(Addnl Ref j, Method No 205 & Addnl Ref l) c)*Primer Mix P-100*: K chlorate 53.0±2.0, Pb thiocyanate 25.0±1.0, Sb sulfide 17.0±1.0, & LA 5.0±1%(Addnl Ref j, Method No 206 & Addnl Ref k) (Compare with Addnl Ref e) d)*Igniter Mix for M31A1* and some other detonator assemblies: K chlorate 55.0±1.0 & Pb thiocyanate 45.0±1.0%

Following are examples of pyrotechnic compns(some of them obsolete) contg K chlorate: a)Rocket red signal compn: K chlorate 25, Sr nitrate 66.6 & orange shellac 8.4%(Ref 5,p 140) b)Red rifle & red Véry pistol light compn: K chlorate 72.7, Sr carbonate 15.2 & orn shellac 12.1%(Ref 5,pp 140 & 182) c)Red position light compn: K chlorate 37.5, Sr nitrate 50 & orn shellac 12.5%(Ref 5,pp 32, 140 & 184) d)Green position light compn(See under Barium Chlorate, Uses) e)Smoke torch blob compn: K chlorate 88.9, red gum(gum Kauri) 7.4 & charcoal(fine) 3.7%(Ref 5,p 140) f)Yellow star compn: K chlorate 70, Na bicarbonate 15 & shellac 15%(Ref 20a,p 206) g)Red star compn: K chlorate 55, Sr carbonate 21, lactose 15, shellac 7 & carbon black 2%(Ref 20a,p 207) h)Red signal compn: K chlorate 76, Sr oxalate 8, shellac 7 & tar 9%(Ref 20,p 207) i)Blue star compn: K chlorate 70, $CuSO_4.4NH_3.H_2O$ 15 & shellac 15%(Ref 20a,p 213) j)Violet star compn: K chlorate 58.5, Sr chlorate 14.5, Cu carbonate 10, sulfur 10 & shellac 7%(Ref 20,p 215) k)Colored smokes compns: K chlorate 28, coloring substances 36, lactose 28, sulfur 4 & Amm chloride 4%(Ref 20a,p 234) l)Various colored smoke compns. See Ref 20a,pp 235-38 m)Russian red light signal compn: K chlorate 57, Sr carbonate 25 & shellac 18%(Ref 22a,pp 73 & 84) n)Rus red smoke compn : K chlorate 35, rhodamine 40 & lactose 25%(Ref 22a,p 73) o)Rus photo

mixt: K chlorate 63 & Mg 37%(Ref 22a,p 84) p)Rus black smoke compns: K chlorate 45, naphthalene 40 & charcoal 15% and K chlorate 55 & anthracene 45%(Ref 22a,pp 241-2) q) Russ blue smoke compn: K chlorate 35, synthetic indigo 40 & lactose 25%(Ref 22a,p 242) r)Rus yellow smoke compn: K chlorate 34.6, aminoazobenzene 40 & lactose 25.4% (Ref 22a,p 251) s)Rus blue smoke compn: K chlorate 35, methylene blue 60 & lactose 5% (Ref 22a,p 252) t)Ger pyrotechnic compns. See Ref 23a,p Ger 154

Ellern(Ref 26,pp 270-80), lists numerous compns contg K chlorate of which the following are examples: A)Military or special safety match: a)K chlorate 88, charcoal 10 & dextrin 2% b)K chlorate 50, Sb sulfide 30 & dextrin 20% and c)K chlorate 60, Sb sulfide (black) 6, ground glass 22.5 & gum arabic 11.5% B)SAW(strike-anywhere) match: K chlorate 32, $P_4S_3$ 10, powdered glass & other filler 33, ZnO 6, rosin 4, animal glue 11 & extender 4% C)Older types, percussion primers: a)K chlorate 53, Sb sulfide 17, Pb thiocyanate 25 & TNT 5%; it was moistened with gum soln & pressed in primer caps while wet and b)K chlorate 41.5, Sb sulfide 9.5, CuCNS 4.7 & ground glass 44.3% D)Electric primer compns: a)K chlorate 60, DADNPh 20, charcoal 15 & NS 5%(suitable for ignition rather than for detonation) and b)K chlorate 55 & Pb thiocyanate 45% E)Colored smokes: K chlorate 22-33, dye 30-50, Na or K bicarbonate 3-10, confectioner's sugar or lactose 20-35, kerosene or paraffin oil 2-4, kieselguhr 0-4 & red iron oxide 0-3% F)'Plastic Bonded' colored smoke: K chlorate 23, dye 51, sugar 18 & K bicarbonate 8%; combined with 2.2 parts of polyvinyl acetate plasticized by dichloro-methane and dried by evapn G)'Cap' mixtures: a)K chlorate 67, red P 27, S 3 & pptd Ca carbonate 3%, bound with unspecified amt of 'gum water' and b)K chlorate 61, red P 4, black Sb sulfide 21,pptd Ca carbonate 2 & animal glue 12% H)Railroad torpedo: K chlorate 40, S 16, sand(60 mesh) 37, binder 5 & neutralizer 2% I)Whistling compns: K chlorate 73-77, gallic acid 24-19 & red gum 3-4%(Ref 26,pp 270-80)

Accdg to Ref 28, there are two grades of K chlorate for use in US ammunition: a)Grade A is intended to be used as an ingredient of primer mixtures and b)Grade B to be used as an ingredient of pyrotechnic mixts

Following are chemical requirements:

| | Grade A | Grade B |
|---|---|---|
| Moisture, max, % | 0.05 | 0.05 |
| $KClO_3$, min, % | 99.5 | 99.5 |
| $H_2O$-insols, max, % | 0.02 | 0.10 |
| pH value | 5-8 | 5-8 |
| Hypochlorites | None | None |
| Chlorites | None | None |
| Chlorides(as KCl), max, % | 0.10 | 0.10 |
| Bromates(as $KBrO_3$), max, % | 0.02 | 0.10 |
| Heavy metals | None | None |
| Alk-earths | None | None |
| Na-salts(as $NaClO_3$), max, % | 0.09 | 0.09 |
| Grit | None | None |

These two grades are subdivided into six classes accdg to granulation(See Table II in Ref 28)

Tests are described under Potassium Chlorate, Analytical Procedures

*Refs:* 1)Escales, Chloratspr(1910), 13-41, 52-61 & 143-49 2)S.Smith, PrChSoc **26**, 124 (1910) & CA **4**, 2206(1910)(Action of sulfuric acid on K chlorate) 3)G.B.Taylor & W.C. Cope, ChemMetEngrg **15**, 141-43(1916) (Hygroscopicity of K chlorate 4)Marshall **1** (1917), 377; **2**(1917), 688 & 759 and **3**(1932), 111-12 5)Faber, Pyrotechnics **3**(1919), 127-50 6)Mellor **2**(1922), 297 & 326 7)C.A.Taylor & W.H.Rinkenbach, "Explosives", USBur-MinesBull **219**, Washington, DC(1923), 32-6 7a)H.Kast, SS **22**, 58-61 & 78-9(1927)(Some expl props of K chlorate) 8)Gmelin, Syst Nr **6**(1927), 337 9)Ullmann **3**(1929), 297-98 10)W.A.Noyes, Jr & W.E.Vaughan, ChemRevs **7**, 240-42(1930), (Thermal decompn of K chlorate) 11)K.A.Hofmann & P.H.Marin, SitzberPreusAkadWissenschPhysik-MathemKlasse **1933**, 450(Thermal decompn of K chlorate alone or in mixts with K nitrate) 12)Stettbacher **1** (1933), 310-11 13)M.Meyer, JChemEduc **17**, 494(1940)(Thermal decompn of K chlorate in presence of chromic oxide & K dichromate) 13a)I.F.Blinov, "Chlorate and Perchlorate Explosives"(in Rus), Oborongiz, Moscow (1941), 40-45 14)A.Alberto & M.R.Liberalli, AnaisAcadBrasilCienc **15**, 373-75(1943) & CA **38**, 2491(1941)(Small amt of $KClO_3$ in TNT greatly increases its sensitivity to shock) 15)Davis(1943), 64-7,70,72,84-8,104,117,119, 123,354-61 & 453-6 16)Pérez Ara(1945),

203-5 17)Anon, OpNav **30-3M**(1945), 28 (Jap expls Ennayaku & Entoyaku using $KClO_3$) 18)Weingart, Pyrotechnics(1947), 60-1,63-4,66-7,72,127,132-6,141-2,146-7,171 & 194-7 19)Kirk & Othmer **3**(1949), 708-16 & **11**(1953), 323 20)CondChemDict(1950), 538 20a)Izzo, Pirotecnia(1950), 204-17, 225-8 & 234-8(Uses of K chlorate in pyrotechnics) 21)ÉtatFrançais, FrP 971644 (1951) & CA **46**, 9311(1952)(Expl powders contg combustible materials & $KClO_3$) 22) S.Yamamoto & T.Asaba, JIndExplSocJapan **13**, 235-41(1952) & CA **49**, 6761(1955)(Effects of inert substances on thermal decompn of $KClO_3$) 22a)Shidlovskii(1954), 21-2, 25,27, 67,73,84-5,91,93,118,187,191,195-6,242, 247-8,250-2 & 254(Props of $KClO_3$ and its uses inpyrotechniccompns) 23)Sax(1957), 1038 23a)PATR **2510**(1958),pp Ger 136 (Primer compns) & Ger 154(Pyrotechnic compns) 24)H.G.Tanner, JChemEduc **36**, 58-9(1959) 24a)F.A.Warren et al, "Chlorates and Perchlorates", NAVORD Rept **7147**(Vol 1) (1960), 68-70 & 142; Ibid, Vol 2(1960)(Conf) (not used as a source of info) 25)I.Huhtanen, Explosivst **1960**, 189-94(Some thermochemical data for $KClO_3$ and its mixts with combustible materials for use in Cheddite-type expls) 26) Ellern, Pyrotechnics(1961), 51,66,97,99,100, 111,126,128,148,171,188,208,254 & 270-80 (Uses of $KClO_3$ in various pyrotechnic compns) 27)Anon, "Pyrotechnics Handbook", Vol 3, Chapter XVI, Ingredients, Part II, McGraw-Hill Technical Writing Service, NY (1962) 28)US Military Specification MIL-P -105A(Potassium chlorate for use in ammunition)

*Addnl Refs:* a)W.R.Tomlinson et al, PATR **1316**(1944)(Percussion- and stab-sensitive compns $KClO_3$-$Sb_2S_3$-MF-abrasive used during WWII in some foreign cartridges as first chge. Mixts $KClO_3$-$Sb_2S_3$-abrasive with occasional addn of carbon or MF used as percussion chges in some foreign fuze primers) b)K.S. Warren, PATR **1411**(1944)(Development of primer mixt for M-5 Chemical Mine Fuze. It consisted of K chlorate & Pb thiocyanate and was similar to std igniting mixt for M-31 detonator) c)K.S.Warren, PATR **1448**(1944) (Mixts of K chlorate with basic Pb 4,6-dinitro-resorcinate were found to be not sufficiently sensitive to initiation in order to serve as possible constituents of primer compns) d)K.S. Warren, PATR **1450**(1944)(Uses of K chlorate in some foreign primers and detonators) e)K.S. Warren, PATR **1569**(1945)(Development of the mixt: K chlorate 50, Pb thiocyanate 35 & Al 15%, which is more suitable for some primers than previously used PA-100 Primer Mix)(See under Potassium Chlorate, Uses) $e_1$)Compagnie de produits chimiques et électrométallurgiques Alais, Froges & Camargue, FrP 969032(1950) & CA **46**, 6388(1952)(Match-head compn contg specially prepd $KClO_3$) f)B.A.Rausch, PATR **2120**(1955)(Development of igniter compn: $KClO_3$ 39.6, $Pb(SCN)_2$ 32.4, charcoal 18 & lacquer binder 10% to replace the flash compn: $KClO_3$ 60, DADNPh 20, carbon 15 & NS 5% for use in electric initiating elements) g)A.M.Anzolone et al, PATR **2179**(1955)(C) h)B.A.Rausch, PATR **2220**(1955)(U) (Evaluation of several styphnate type primer compns as possible substitutes for std chlorate-based compns in percussion primers) i)A.M.Anzalone, PATR **2227**(1955)(C) j) A.R.Lusardi, "Laboratory Manual", Expls & PropIntsLab, PicArsn, Dover, NJ(1962), Methods 202,203,204,205,206,208 & 209 k)US Military Specification **MIL-D-2493** (superseding PA-PD-124) l)US Military Spec **MIL-P-20449A**(superseding MIL-E-20449)

**Potassium Chlorate, Analytical Procedures.** Chlorate ion can be detected and detd as described under Chlorates, Analytical Procedures. Potassium ion may be detected by dipping a Pt wire moistened with concd HCl into powdered sample and heating it in the non-luminous flame of a Bunsen burner. If the color of flame is violet, the salt is fairly pure(Ref 1,p 141 & Ref 3,p 862). K can be identified by pptg it as $K_2NaCo(NO_2)_6$, as well as by potassium salts of chloro-platinate, perchlorate, acid tartrate, picrate, silicofluoride, etc(Ref 3,p 862). Various quantitative methods for detn of K ion are given in Refs 3,4,4a & 8

Analyses of commercial K chlorates are given in Refs 1,2,7 & 10. Determinations of K chlorate in mixts with other ingredients are given in Refs 1,3,5,7,9,11,12,13 and under Cheddites, Analytical Procedures

Following are US Military Specification tests:

*A)Moisture.* Heat a 10g, accurately weighed sample together with a tared container, for 5hrs at 100°, cool in a desiccator and weigh. Save the sample for next opn

*B)K chlorate content.* Weigh accurately a

0.15g sample of dry material(saved from opn A), dissolve in 100ml of distd w contained in a 500ml Erlen fl and add exactly 50ml of an 8% soln of $(NH_4)_2Fe(SO_4)_2.6H_2O$(Mohr's salt). Close the flask with Bunsen valve and heat the soln to boiling. Two mins after steam ceases to emit from the valve, cool the flask rapidly to RT and remove the valve. Add 10ml of Zimmermann-Reinhardt reagent(prepd by cautiously adding 12.5ml of concd sulfuric acid & 12.5ml of phosphoric acid to 7g of $MnSO_4.4H_2O$ dissolved in 50ml of w, and diluting the mixt to 100ml), shake and titrate the excess of Mohr's salt with std 0.1N soln of K permanganate. Concurrently run the blank value for exactly 50ml of 8% Mohr's salt

$$\%KClO_3 = [2.043(V-v)N]/W,$$

where V = ml of $KMnO_4$ required for blank, v = ml required for sample soln; N = normality of $KMnO_4$; and W = wt of dry sample

*C)Water-insoluble material.* Dissolve ca 50g of original sample in ca 650ml of warm distd w filter the soln thru a tared filtering crucible and wash the residue with 5 portions of hot w. Dry the crucible for 1hr at 105°, cool it in a desiccator and weigh. Save the filtrate and residue for subsequent opns

*D)pH value.* Cool the filtrate from opn C to RT, transfer it to a 1000ml volumetric flask and dilute to the mark. Remove part of soln and det its pH by means of a standardized pH meter

*E)Hypochlorites.* Dip a strip of KI-starch paper into the soln used for pH test and if the paper does not turn immediately blue, hypochlorites are absent. Save the soln for opn F. If the paper turns blue(which indicates the presence of hypochlorites), the test for chlorites should be disregarded

*F)Chlorites.* If hypochlorites are absent add to soln of opn E ca 2ml of 0.1N sulfuric acid and dip the KI-starch paper. If it does not turn immediately blue, chlorites are absent

*G)Chlorides.* Pipette out 100ml aliquot(of soln prepd in opn D) into a white porcelain dish, add 1ml of 5% K chromate soln and titrate with the soln (contg exactly 4.791g of pure, dry Ag nitrate per 1000ml of aq soln) to the first perceptible color change. Run concurrently a blank by titrating under the same conditions of lighting and background, 100ml of distd w contg 1ml of the same K chromate soln to the same color change

$$\%KCl = [0.21(V-v)]/W,$$

where V = ml of Aq chloride required for sample soln; v = ml required for blank; W = wt of sample in 100ml aliquot, calcd on the dried sample

*H)Bromates.* Pipette a 200ml aliquot(from soln prepd in opn D) into a 500ml glass stoppered iodine flask, add 5ml of 1:9 HCl-w soln and 5ml of freshly prepd 10% KI soln followed by 5ml of starch indicator. Stopper the flask, shake it and set in a dark place for 1hr. Titrate the contents with 0.02N Na thiosulfate soln until the blue color disappears. Run concurrently a blank using 200ml of distd w and the same reagents as above

$$\%KBrO_3 = [2.783(V-v)N]/W,$$

where V = ml Na thiosufate used for sample titration; v = ml for blank; N = normality of Na thiosulfate soln; and W = wt of sample in 200ml aliquot calcd on the dried sample

*I)Heavy metals.* Acidify 25ml aliquot from opn D soln with 0.1N HCl soln and bubble $H_2S$ gas thru the soln for ca 30 secs. No pptn or coloration should result

*J)Alkaline-earth metals.* Alkalize 25ml aliquot from opn D with 1ml of 10% Amm hydroxide soln, add 5ml of 10% Amm oxalate soln and heat the mixt nearly to boiling. No ppt should be formed on cooling

*K)Sodium salts,* are detd gravimetrically by means of magnesium uranyl acetate reagent, using a 20g sample. As this, rather tedious method, is essentially the same as described in the literature(See Ref 3,pp 879-81 and Ref 8,pp 558-60), no description is given here

*L)Grit.* Place the water-insol residue of opn C on a small smooth glass plate and rub with a smooth steel spatula or blade. Any rough particles which behave in the manner similar to sand, when it is ground betw glass and steel, should be considered as grit

*M)Granulation.* For classes 1,2,3,4 & 5 a 100g sample is shaken on appropriate set of sieves 10mins by hand or 5mins by means of a mechanical shaker geared to produce 300±15 gyrations and 150±10 taps of the striker per min. The portions retained or passed by the various sieves should be weighed and the results calcd to the percentage basis. For class 6, a 10g sample is placed on a dry tared, 3" diam No 325 US Std sieve, and washed with a steady gentle stream of isopropanol(previously saturated with K chlorate at 25±5°) from a wash bottle, breaking up any lumps by means of a glass rod. During

the washing the sieve should be shaken gently and occasionally the bottom of the screen tapped. Washing should be continued until no more sample passes thru the sieve; then the sieve is dried on a steam bath and in an oven at 100-105° for 15mins, cooled in a desiccator and weighed. No more than 5% of sample should be retained on the sieve

Tests conducted at the Bofors labs(Ref 7) include the following:

*a)Appearance.* White and free from mechanical impurities

*b)$KClO_3$ content.* Dissolve an accurately weighed 0.5g sample in 200ml distd w contained in a 400ml tall beaker, add & dissolve 5g of Na nitrite(chloride-free) and then 50ml of 0.1N Ag nitrate soln. Cover the beaker with a watch glass and boil gently in a hood(while adding distd w occasionally to maintain the original volume), until the evoln of nitrous fumes ceases. Cool and add 5ml of 10% ferric alum soln(contg 10ml of concd nitric acid per liter) as indicator and titrate with 0.1N Amm thiocyanate soln. Run concurrently a blank detn

$$\%KClO_3 = [12.255(b-a)n]/w,$$

where b = ml of thiocyanate soln used for sample; a = ml used for blank; n = normality of thiocyanate soln; and w = wt of sample

*c)Bromates.* The method is essentially the same as the US spec method, described here as H, except that a 2g sample is used and Na thiosulfate soln is 0.01N. Starch indicator is a 1% aq soln

*d)Water-insoluble matter.* The method is essentially the same as the US spec method described here as C, except that a 10g sample dissolved in 200ml distd w is used. The filtering crucible is of medium porosity, such as Jena IG3 or Pyrex M. Save the filtrate

*e)Perchlorates.* Det them qualitatively by adding to 10ml of filtrate from previous opn, 0.5ml of 0.3% aq soln of methylene blue. In the presence of perchlorates, a violet ppt with green fluorescence is formed

*f)Nitrates.* Mix in a test tube a few mls of opn d filtrate with 1ml dil sulfuric acid and some cold satd ferrous sulfate soln. While keeping the test tube inclined, let a few mls of concd sulfuric acid run slowly(from a pipette) down along the inner side of the tube, so that the acid does not mix with the aq soln but forms a layer under it. If nitrates are present, a dark brown ring will appear at the contact surface betw the two liquids

*g)Chlorides.* Acidify slightly with dil nitric acid 10ml of filtrate from opn d and add 1ml of 10% Ag nitrate soln. If turbidity is obtained within 5mins, chlorides are present. Compare the turbidity with those obtained with solns contg known amts of chlorides (Ref 7)

For large amts of chlorides, detn is made by titrating a neutral soln of sample with 0.1N Ag nitrate soln using ca 10 drops of 10% K chromate indicator, to the first reddish coloration(For details see Ref 7,p 103)

*h)Sulfates.* Acidify slightly with dil HCl(1:1) 10ml of filtrate from opn d and add 1ml of 10% Ba chloride soln. If turbidity is obtained within 15mins, sulfates are present. Compare the turbidity with those obtained with solns contg known amts of sulfates(Ref 7,p 103)

For large amts of sulfates, detn is made by gravimetric method described in Ref 7,p 103

*i)Heavy metals.* Acidify 10ml of filtrate from opn d with 0.5ml of 10% HCl soln and bubble hydrogen sulfide thru it for 1min. Dark coloration or ppt indicates heavy metals

*j)Alkaline-earths.* Alkalize 10ml of filtrate from opn d with 0.5ml ammonia, add 2ml of 10% Amm oxalate soln, heat to nearly boiling and then cool. Ppt or turbidity indicates the presence of alkaline-earths

*k)Ammonium salts.* Warm in a test tube a 1g sample with 10ml of 10% NaOH soln and if ammonia is evolved(as indicated by odor or by moistened litmus paper held in the opening of the test tube), the sample contains an Amm salt

*l)Sodium salts.* Heat a clean Pt wire over a Bunsen flame until no yel flame is visible, cool, plunge into a satd soln of sample and hea as above. Yel coloration of flame indicates the presence of appreciable amt of Na salt. If only traces are present a very pale yel color is observed besides the characteristic violet color of K salt

A more precise "flame spectrophotometric method" is given in Ref 6

*m)Reaction.* Dissolve a 10g sample in 200ml of hot distd w, cool, filter thru a coarse paper and wash the filter with 50ml distd w. Divide the filtrate into two parts and add to one part a few drops of methyl red indicator and to another part a few drops of phenol-

phthalein soln. If the 1st part turns red the soln is acid and if the 2nd part turns pink, the soln is alkaline

*n)Moisture* is detd by heating a 5-10g sample at 100° for 2hrs or by Karl Fischer method (Ref 7,p 15)

*o)Granulation* is detd as described in Ref 7,p 23. US Std sieves or Tyler sieves can be used

Bofors AB also describes(Ref 7,p 150), the following colorimetric method for detn of chlorates in perchlorates: Mix a 2g sample with 2ml of aniline reagent(3.6g of aniline dissolved in 100ml of 1:1 HCl soln) and 0.5ml distd w. If a blue or green coloration appears within 30mins, chlorates are present. Det the contents as $KClO_3$, by comparing the color of soln with these obtained with solns of pure $KClO_3$ of known contents

Determinations of K chlorate in expls are similar to those described under Cheddites, Analytical Procedures

Determinations of K chlorate in primer- and igniter- compns are described in Refs 5,9,11, 12 & 13

Following procedure was developed in 1950 at PicArsn and is incorporated in Spec MIL-D-2493(Ref 12,pp 6-7). It is applicable to mixes contg K chlorate, Sb sulfide, LA & Pb thiocyanate

*Prepn of wash solns:*

*Soln No 1.* Add to ca 800ml of distd w in 1 liter amber glass bottle, ca 40g of K thiocyanate, insert a rubber stopper and shake until complete dissolution. Add to this soln 1.0g Pb thiocyanate, 1g of Sb sulfide and 1g of LA; restopper the bottle, shake vigorously for ca 10mins and allow it to stand overnight. When necessary, remove a portion required for complete test, filter it before using and transfer to a burette

*Soln No 2.* Add to ca 400ml of distd w in a one-half liter amber glass bottle, 1.0g of Pb thiocyanate, 1.0g of Sb sulfide & 1.0g of LA; insert a rubber stopper, shake vigorously for ca 10mins and allow it to stand overnight. Filter before using a portion required for complete test and transfer to a burette

*Procedure.* Weigh a 1g sample(previously dried at ca 65°) in a tared 30ml sintered glass crucible of medium porosity, add from the burette 3.0ml of soln No 1 and swirl the crucible for exactly 1min taking care not to spill any liquid. Remove the liquid by suction, disconnect the crucible from adapter in the neck of suction flask, and wipe the bottom of crucible with tissue paper. Repeat the above opns, first with another 3.0ml portion of soln No 1, then with two 2.0ml, and two 1.0ml portions making a total of 12.0ml of soln No 1. Remove the crucible, discard the filtrate and wash with distd w the outside of crucible, the adapter and suction flask. These opns are supposed to remove completely K chlorate, leaving other ingredients of primer mix intact. In order to verify the completeness of washing, swirl the crucible with another 1ml portion of soln No 1 and transfer the liq by suction to a test tube. Mix its contents with 1ml distd w, incline the tube at an angle of ca 45° and add slowly from a dropper ca 0.5ml of diphenylamine reagent(1g of DPhA dissolved in 100ml of concd sulfuric acid) in such a manner that it runs along the inner side of the tube without mixing with soln No 1 but forms a layer under it. If an appreciable amt of chlorate ion is present, a distinct blue ring will be visible at the junction of the two layers. On shaking the tube, the ring disappears, but the contents assumes a blue coloration, which lasts several seconds depending on the amt of chlorate ion present. If only a trace of chlorate ion is present, the blue ring may not form, but upon shaking the test tube, a slight bluish coloration will appear momentarily throughout the soln, lasting only a fraction of a second. If a definite blue ring forms, repeat the washings as before using one 1.0ml portion of soln No 1, followed by 0.5ml portion. Usually not more than a total of 14.5ml is required

After complete removal of K chlorate, swirl the crucible once with 1.0ml of soln No 2 and remove the liquid immediately by suction. Wipe the bottom of crucible with tissue paper, dry the crucible in an oven at $80\pm1°$ for 30mins, cool in a desiccator and weigh

$$\%KClO_3 = (100B)/W,$$

where B = loss in wt of the contents of crucible and W = wt of the sample on a moisture-free basis

For detn of other ingredients: Sb sulfide, LA & Pb thiocyanate, see Ref 12,pp 7-9

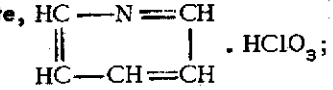
If the mix does not contain Pb thiocyanate the wash solns do not contain any thiocyanate and in some cases the washing may be conducted by using LA-satd distd w as described

in Ref 12,p 9

For an igniting mix consisting of K chlorate 55 and Pb thiocyanate 45%, the thiocyanate is detd first by the method described in Ref 12,p 10 and K chlorate is calcd by subtracting Pb thiocyanate content from 100

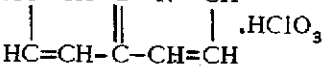
For primer mix No 70, the ingredients: TNT, Sb sulfide and Pb thiocyanate are detd as described in Ref 13, while the remaining ingredient K chlorate + gum is calcd by subtracting from 100 the sum of other ingredients

*Refs:* 1)Faber **3**(1919), 141-50 2)C.A.Taylor & Wm. H. Rinkenbach, "Explosives", USBurMinesBull **219**(1923), 32-6(Analysis of commercial K chlorate); 142-3(Detn of K chlorate in dynamites) 3)Scott & Furman (1939), 274-6, 861-70, 1677 & 2160 4) Treadwell & Hall, vols 1 & 2(1942) 4a) Kast-Metz(1944), 373-80(Analysis of commercial K chlorate) 5)Anon, "Control Laboratory Manual", Expls & Proplnts Branch, PicArsn, Dover, NJ(1956); Method No 501.1(Analysis of M31 Igniting Mixture); Method No 502.1 (Analysis of PA-100 Primer Mixture); Method No 503.1(Analysis of Standard Primer Mixture) 6)M.Halik & R.Croom, PATR **2430**(1957)(U) (Flame spectrophotometric method for detg Na chlorate in K chlorate) 7)Anon, "Analytical Methods for Powders and Explosives", AB Bofors Nobelkrut, Bofors, Sweden(1960), 148-9(Analysis of commercial K chlorate); 150(Colorimetric detn of chlorates in K perchlorate) 8)Vogel, InorgAnalysis(1961), 313,361-2,399,412,560-4,571,723 &.885 9) A.R.Lusardi, "Laboratory Manual", Expls & Proplnts Lab, PicArsn, Dover, NJ(1962), Methods 202,203,204,205,206,208 & 209 (Analyses of primer and igniter mixts contg K chlorate) 10)US Military Specification **MIL-P-150A**(K chlorate for use in ammunition) 11)US Joint Army-Navy Specification **JAN-P-217**(or **PA-PD-254**)(Detn of K chlorate in K perchlorate) 12)US Military Specification **MIL-D-2493**(Superseding PA-PD-124)(Analyses of various primer and igniter mixts) 13) US Military Spec **MIL-P-20449A**(Ord)(Superseding MIL-E-20449)(Analysis of No 70 primer compn)

**Pyridine Chlorate,**  .$HClO_3$;

mw 165.56, N 8.56%; wh crysts(from alc) having soft, soapy touch & odor of pyridine, mp 147° with decompn; sol in w or alc; insol in nondissociating org solvs; was prepd by heating a concd aq soln of $HClO_3$ on a water bath with a sl excess of pyridine. This compd burns with a sudden flash when touched with a flame or in contact with concd $H_2SO_4$

*Refs:* 1)Beil **20**,(58) 2)R.L.Datta & J.K. Choudhury, JACS **38**, 1083-84(1916)

**Quinoline Chlorate,**  .$HClO_3$;

mw 213.62, N 6.56%; yellowish hygr crysts, mp 66-7°; sol in w or alc but cannot be recrystallized from these solvs; was prepd by heating an aq soln of $HClO_3$ with a sl excess of quinoline and purifying the prod by washing with a mixt of alc & eth. This compd decomp with a flash and a large amt of smoke when touched with a flame or in contact with concd $H_2SO_4$, leaving a blk residue

*Refs:* 1)Beil **20**,(136) 2)R.L.Datta & J.K. Choudhury, JACS **38**, 1084(1916)

**Silver Chlorate,** $AgClO_3$; mw 191.34; exists in two forms: stable wh, opaque tetragonal prisms(d 4.42-4.44) and labile cubic crysts (d 4.21); mp 230°, bp dec at 270°, evolving oxygen; sol in w or alc; was prepd in 1802 by R.Chenevix(See in Ref 2), by passing chlorine gas into w in which silver oxide was suspended. It can also be prepd by dissolving $Ag_2O$, or finely divided metallic Ag, in chloric acid(Ref 2). Its method of prepn from $AgNO_3$ & $NaClO_3$ is described by Nicholson & Holley(Ref 5)

Silver chlorate is a strong oxidg agent and forms powerful expl mixts with combustible materials. According to A.Wächter(See in Ref 2), silver chlorate alone can decomp explosively when heated very rapidly

Bruni & Levi(Ref 1) prepd an expl compd *Triamminesilver Chlorate,* $AgClO_3 \cdot 3NH_3$, by the action of ammonia on $AgClO_3$

*Refs:* 1)G.Bruni & G.Levi, Gazz **46** II, 17 (1916) 2)Mellor **2**(1922), 340 3)Gmelin, Syst Nr **6**(1927), 339-40 4)Ullmann **3**(1929), 299 5)D.G.Nicholson & C.E.Holley, Jr, Inorg Synth **2**(1946), 4-6 6)Sidgwick, ChemElems **1**(1950), 128 7)Sax(1957), 1104 8)F.A.Warren et al, "Chlorates and Perchlorates", NAVORD Repr **7147**(Vol 1) (1960), 141

**Sodium Chlorate,** $NaClO_3$; mw 106.45; reported

in Mellor(Ref 3) to be tetramorphous, forming: a)cubic b)unstable rhombic c)unstable monoclinic and d)rhombic or pseudo-cubic crystalline forms; col, odorless cubic crysts are the common form; mp 248-61°, bp decomp; d 2.490 at 15°; $n_D$ 1.515 at 20°; sol in w, alc, alkalies, and aq solns of NaCl, glycerol and liq ammonia(Ref 3)(See also Refs 5,6,11 & 18b)

Methods of prepg $NaClO_3$ are the same as those for $KClO_3$, except that Na salts are used. Detailed description of methods of prepn are given in Refs 1,5 & 11. The present coml method is by electrolysis of hot concd aq soln of NaCl(Refs 8,9 & 11)

Sodium chlorate decomp when heated or in contact with combustibles or concd acids, in the same manner as the potassium salt. Although it is a powerful oxidg agent and contains more oxygen per unit wt than $KClO_3$, it has not found wide use in expls due to its extreme hygroscopicity & high sensitivity. According to Faber(Ref 2), one of the principal reasons why $NaClO_3$ is dangerous is due to the deliq & subsequent effl of the material causing segregation of fine crysts which are highly reactive. An expln which cost the lives of 4 persons and injured several others occurred in the chemistry bldg of Howard University, Washington, DC on 27 March 1952. The blast resulted when ca 400 lbs of sodium chlorate was being removed from a basement storage room(Ref 16). The investigating committee reported that a static elec spark, believed to have been generated when a worker grasped the metal handles of the loaded hand truck, caused the expln & fire. The report recommended $NaClO_3$ should never be stored in a general storage area, but it should be stored for lab use in glass bottles contg not over 1-lb(Ref 17)

Details concerning the props, hazards and percautions in handling & storing $NaClO_3$ are discussed by Mattair(Ref 15) and in MCA safety booklet(Ref 14)

*Explosive Properties.* They are comparable to those of K chlorate. Expls contg $NaClO_3$ possess slightly higher power than those contg an equal proportion of $KClO_3$. For example, among the expls listed by L.Médard, MP **32**, 210(1950), the one contg 90% $NaClO_3$ & 10% paraffin is about 8% more powerful than the corresponding expl contg $KClO_3$

*Uses:* Na chlorate, being hygroscopic, was not used in older expl compns until a method was found to waterproof the substance. This was achieved by coating the grains of Na chlorate with oily, greasy or plastic materials (such as castor oil, vaselin, paraffin, etc) and the resulting expls became known as CHEDDITES(qv), also called Streetites or Street Explosives. Some of these expls were used by the French during WWI for military purposes, such as demolition work and for loading grenades, mines and trench mortar bombs. Coating of grains not only rendered them less hygroscopic but it also made them less sensitive to friction and impact(See also Refs 1,6 & 11). Babor(Ref 8) waterproofed the crysts of Na chlorate by coating them with 4% collodion soln, followed by drying. Several expl compns contg Na chlorate and combustible materials were patented in France after WWII(Ref 13). A Na chlorate expl developed during WWII by Kiernan & Bowen was tested at PicArsn and found to be unsuitable for military purposes(Ref 10a). Some Ger Na chlorate expls, such as Chloratits, Gesteins-Koronits and Miedziankit, are listed in Ref 18a. $NaClO_3$ has also been used in manuf of matches(Ref 12) and in some pyrotechnic compns(Ref 20). Kirk & Othmer(Ref 11) lists its principal uses as an intermediate in the manuf of perchlorates and in weed killers

CPCEM(Compagnie de produits chimiques et électrométallurgiques) Alais, Frogues & Camargue patented recently [FrP 992332(1951) & CA **50**, 11020(1956)], a pyrotechnic mixt of a chlorate or a nitrate and tar, such as Na chlorate 80 & tar 20% made in the form of a rod 6mm in diam and 170mm long, covered with a 0.1mm synthetic resin layer. The rod burns for 95sec developing a temp of 1400-1600°. Immersion in water for 3hrs did not impair its burning characteristics

US Military Spec(Ref 21) covers the reagent-grade Na chlorate and the requirements are:

| | |
|---|---|
| a)$NaClO_3$ content, minimum | 99% |
| b)Insolubles, maximum | 0.010 |
| c)Bromate(as $BrO_3$), max | 0.07 |
| d)Chloride(as Cl), max | 0.005 |
| e)Nitrogen compds(as N), max | 0.001 |
| f)Sulfate(as $SO_4$), max | 0.003 |
| g)Ca,Mg & Amm hydroxide precipitate, max | 0.01 |
| h)Heavy metals(as Pb), max | 0.001 |

| | |
|---|---|
| i)Iron(as Fe), max | 0.0005 |
| j)Form | Crysts |
| k)Color | Colorless |

Accdg to Belgrano(Ref 16a) a good Na chlorate, suitable for Cheddites should possess the following properties: $NaClO_3$ min content 99.50%, NaCl max 0.05%, insolubles max 0.04%, and moisture max 0.07%

*Refs:* 1)Escales, Chloratspr(1910), 41,61 & 128 2)H.B.Faber, "Military Pyrotechnics", US GovtPrintOfc, Washington, vol **3**(1919), 128ff 3)Mellor **2**(1922), 325 4)C.A.Taylor & W.H.Rinkenbach, "Explosives", USBur-MinesBull **219**, Washington(1923), 36 5) Gmelin, Syst Nr **6**(1927), 337, 340 6) Ullmann **3**(1929). 298 7)Stettbacher **1**(1933), 314 8)M.Babor, BullSectSciAcadRoumaine **19**, 213-18(1937-38) & CA **34**, 5661(1940) 9)A.L.Pitman et al, ChemMetEngrg **45**, 692-96 (1938)(Production of sodium chlorate by electrolytic method) 10)Davis(1943), 357-66 10a)J.Phillips, PATR **1277**(1943)(Study of $NaClO_3$ explosive developed by Kiernan & Bowen) 11)Kirk & Othmer **3**(1949), 708-16 12)CondChemDict(1950),604 13)ÉtatFrançais, FrP 971644(1951) & CA **46**, 9311(1952) 14)Anon, Manufg Chemists Assoc, Chemical Safety Data Sheet **SD-42**(1951),11pp & CA **46**, 5319(1952) 15)R.Mattair, PaperInd **33**, 1187-88(1952) & CA **46**, 3761(1952) 16)Anon, C & EN **30**, 1416 & 1420(1952) 16a)Belgrano (1952), 178(Na chlorate for Cheddites) 17) O.R.Ewing, C & EN **30**, 3210(1952) & CA **46**, 9845(1952)(Abstract incorrectly lists site of expl as Catholic Univ instead of Howard Univ) 18a)PATR **2510**(1958),pp Ger 28(Table 8) & Ger 69 18Sax(1957), 1114 18b)Cond-ChemDict(1961), 1037 19)F.A.Warren et al, "Chlorates and Perchlorates", NAVORD Rept **7147**(Vol 1)(1960), 67-8 20)Ellern, Pyrotechnics(1961), 148,171,256 & 259 21) US Specification **MIL-S-11169**(Requirements for Na chlorate, reagent grade)

**Sodium Chlorate, Analytical Procedures.** Chlorate ion may be detected and detd as described under Chlorates, Analytical Procedures. Sodium ion may be detected by the color it imparts to a flame, or by means of the spectroscope. The procedure is described in Ref 1,p 875(See also Ref 2). For quantitative detn of Na, it can be precipitated as Zn-, Mg-, Co- or Ni-, uranyl acetate as described in Refs 1,2 & 5. Other methods, such as pptn as Na pyroantimonate or as Na cesiumbismuth nitrate, may be used

Na chlorate intended for US military use is analyzed as prescribed in Ref 6. The procedures are as follows:

*A)$NaClO_3$ content.* Weigh accurately a 0.1g sample(previously dried over concd sulfuric acid for 24hrs) and dissolve it in 10ml distd w in a 250ml Erlen fl. Add 35.0ml of acid ferrous sulfate soln(prepd by dissolving 7.00g of ferrous sulfate in 90ml freshly-boiled distd w and addg sufficient amt of concd sulfuric acid to make 100ml), close the flask with a stopper provided with Bunsen valve and boil gently for 10mins. Cool, add 10ml of 10% manganous sulfate soln and titrate the excess ferrous sulfate with 0.1N K permanganate soln. Run concurrently a blank with 35.0ml acid ferrous sulfate

$$\%NaClO_3 = [(A-B) \times 0.1774] / W,$$

where A = ml of K permanganate soln used in the blank, B = ml used in the sample test and W = wt of sample

*B)Insolubles.* Dissolve a 10g sample in 10ml of hot distd w, heat on a steam bath for 1hr, filter thru a tared sintered glass crucible, rinse it with hot w, dry at 105±3°, cool in a desiccator and weigh

*C)Chloride.* Dissolve exactly 2.000g of sample in 40ml of hot distd w, (contained in a 100ml Nessler tube), cool, add 5 drops of nitric acid(free from nitrogen oxides) and 1ml of Ag nitrate(prepd by dissolving 1.700g of $AgNO_3$ in sufficient w to make 100ml). Prepare a blank in another Nessler tube with 40ml of w, 5 drops of nitric acid, 1ml of Ag nitrate and 0.10mg of NaCl(or 1ml of a soln contg 0.1649g NaCl in 1 liter). If the turbidity in the sample tube is greater than in the blank, the material does not comply with requiremtnt of Ref 6

*D)Bromate.* Dissolve exactly 2.000g of sample in 200ml of freshly boiled and cooled w in a glass-stoppered flask, add 10.0ml of 1N HCl, mix, and add 10ml of freshly prepd 10% KI soln followed by 5ml of freshly prepd starch indicator. Stopper immediately, swirl gently to mix the contents and allow it to stand for 1hr protected from light. Titrate with 0.1N Na thiosulfate solution until the blue color disappears. If more than 0.65ml of thiosulfate is required, the material does not comply with requirement of Ref 6

*E)Nitrogen compounds.* Dissolve exactly 2.000g of sample in 40ml distd w, add 1.000g of powdered Devarda's metal and 20ml of 10%

NaOH. Stopper the flask and, after allowing it to stand in a cool place for 2hrs, distil 40ml, collecting the distillate in 5ml of w contg 1 drop of dil HCl. Add to the distillate 1ml of 10% NaOH and 2.0ml of Nessler's soln (prepd as described in Ref 1,p 630, Footnote 2). Prepare a control with 0.02mg of nitrogen by treating 2ml of a soln contg 0.0382g of $NH_4Cl$ in 1000ml of w in the same manner as the 2g sample. If the color of test soln is darker than the control, the sample does not comply with spec requirement

*F)Sulfate.* Dissolve exactly 3.000g of sample in 100ml of w, add 1ml of 10% HCl and 5ml of Ba chloride soln(prepd by dissolving 12.00g $BaCl_2$ in sufficient w to make 100ml). Allow it to stand overnight and if any turbidity or ppt forms, the sample does not comply with requirements of spec

*G)Ca, Mg and Amm hydroxide precipitates.* Boil a soln of 10.00g sample in 50ml of w and 15ml of 37% HCl until no more chlorine is evolved. Dilute to 120ml with w, heat to boiling, add 5ml of Amm oxalate soln(prepd by dissolving 4.000g in sufficient w to make 100ml), 3ml of Amm phosphate soln(prepd by dissolving 13.00g of dibasic Amm phosphate in sufficient w to make 100ml) and 20ml of 28% Amm hydroxide. Allow it to stand overnight and if a ppt is present, filter, wash with 2.5% Amm hydroxide and ignite. If the wt of the residue exceeds 0.0010g, the sample does not comply with requirements of spec

*H)Heavy metals.* Evaporate to dryness on a steam bath a mixt of 5.000g of sample with 15ml of hot w & 10ml of 37% HCl and dissolve the residue in 50ml of w. Treat 10ml of this soln with 2ml of the soln(prepd by dissolving 0.0160g of Pb nitrate in 1000ml of w)which is equivalent to 0.02mg of Pb, dilute to 30ml with w and add 1ml of 1N acetic acid(Soln A). Treat 30ml of original 50ml soln with 1ml of 1N acetic acid and designate it as Soln B. To both solns add 10ml of freshly-prepd satd aq soln of hydrogen sulfide and if Soln B is darker than Soln A, the sample does not comply with spec requirement

*I)Iron.* Add to the remaining 10ml from the test H, 15ml of butanolic potassium thiocyanate soln(prepd by dissolving 10.00g of K thiocyanate in 10ml of w, warming to ca 30°, adding sufficient n-butanol to make 100ml and shaking vigorously until clear), shake vigorously for 30secs, and allow it to separate. Prepare a control by mixing 0.50ml of the soln contg 0.005mg of iron [prepd by dissolving 0.08635g of $NH_4.Fe(SO_4)_2.12H_2O$ in 10ml of 10% sulfuric acid and adding sufficient w to make 100ml] with 10ml of w, 1ml of 37% HCl, 15ml of butanolic K thiocyanate, shake vigorously and allow it to separate. If the red color in butanol layer in the sample mix is darker than the control, the material does not comply with spec requirement

Kaye(Ref 3) describes a method for detn of purity of Na chlorate by titration in nonaqueous medium and Halik & Croom(Ref 4) give a flame spectrophotometric method for detg Na chlorate in K chlorate

*Refs:* 1)Scott & Furman(1939), 875-8 2) Treadwell & Hall(1942), vols 1 & 2 3)S. Kaye, PATR **1947**(1953)(Detn of purity of inorg compds of ordnance interest by titration in nonaqueous medium) 4)M.Halik & R. Croom, PATR **2430**(1957) 5)Vogel, Inorg-Analysis(1961), 557-9, 663, 722-3 & 885 6)US Military Specification **MIL-S-11169**(tests for Na chlorate, reagent grade)

**Strontium Chlorate,** $Sr(ClO_3)_2$, mw 254.54; wh rhmb crysts, mp dec 120°, d 3.152; sol in w, insol in alc; was obtd in 1843 by A.Wächter (See in Ref 2) on warming, over concd $H_2SO_4$, a soln obtd by neutralizing aq $HClO_3$ with either $Sr(OH)_2$ or $SrCO_3$. The anhyd salt may also be obtd by heating the octahydrate or other hydrates to ca 120°. *Monohydrate,* $Sr(ClO_3)_2.H_2O$, is listed in Ullmann(Ref 2). *Trihydrate,* $Sr(ClO_3)_2.3H_2O$, is reported in Mellor(Ref 1) as having been obtd by A. Potilitzin in needle-like crysts by cooling a 59% soln of strontium chlorate to -40°, and rhmb prisms by cooling a 64% soln to -20 to 25°. *Octahydrate,* $Sr(ClO_3)_2.8H_2O$; mw 398.67; wh ndls, mp(looses $8H_2O$ at 120° & decomp at 290°); sol in w, sl sol in alc; coml salt can be prepd either by electrolysis of strong aq soln of $SrCl_2$ or by passing chlorine gas thru a warm aq soln of $Sr(OH)_2$ with subsequent evapn of the w and crystn of the octahydrate

*Uses:* The octahydrate is used as an oxidg agent in expls, exercizing a cooling effect due to the large amt of w of crystn, and in pyrotechnic compns for producing a red light (Refs 3a,4,5a & 7). Izzo(Ref 4a) gives the following compn for violet light star: Sr chlorate, 14.5, K chlorate 58.5 , Cu carbonate 10, sulfur 10 & shellac 7%

*Refs:* 1)Mellor **2**(1922), 345 2)Ullmann **3** (1929), 299 3)Gmelin, Syst Nr **29**(1931), 143ff and Nr **29**(1960), 220ff 3a)Davis(1943), 86 4)CondChemDict(1950), 629 4a)Izzo, Pirotecnia(1950), 215 5)Sidgwick, ChemElems **1**(1950), 257 5a)Shidlovskii(1954), 27-8 6)Sax(1957), 1138 7)CondChemDict(1961), 1080 8)Ellern, Pyrotechnics(1961)-not found

**Strontium Chlorate, Analytical Procedures.** Chlorate ion may be detected and detd as described under Chlorates, Analytical Procedures and strontium ion as described in Refs 2,3 & 4. The complete analysis of salt may be done in the manner described by Faber(Ref 1) for Ba chlorate. The method is outlined here under Barium Chlorate, Analytical Procedures. There is no US Military Specification

*Refs:* 1)Faber, Pyrotechnics **3**(1919), 160-4 2)Scott & Furman(1939), 899-902 3)Treadwell & Hall(1942), Vols 1 & 2 4)Vogel, Inorg Analysis(1961), 552-3

**Tetramethylammonium Chlorate,** $N(CH_3)_4 \cdot ClO_3$; mw 157.59; N 8.89%; wh crysts, mp explodes at 230°; sol in alc or w; was prepd by double decompn of tetramethylammonium iodide & $AgClO_3$ and evapg the soln on a w bath to crystn. This compd suddenly flashes in contact with a flame or in contact with concd $H_2SO_4$(Refs 1 & 2)

Datta & Choudhury(Ref 2) also prepd *Tetraethylammonium Chlorate,* $N(C_2H_5)_4 \cdot ClO_3$, wh crysts, mp 223°(dec); and *Tetrapropylammonium Chlorate,* $N(C_3H_7)_4ClO_3$, wh crysts, mp 217° but neither salt is expl. However, they both take fire easily when in contact with a flame or concd $H_2SO_4$

*Refs:* 1)Beilstein **4**,(326) 2)R.L.Datta & J.K. Choudhury, JACS **38**, 1084-85(1916)

**Thallous Chlorate,** $TlClO_3$; mw 287.85; col needle-like crysts, mp dec, d 5.505 at 9°; sl sol in cold w, readily sol in hot w; was prepd by dissolving the metal in chloric acid, or by mixing $KClO_3$ & thallous nitrate, or as recommended by J.Muir(See in Ref 1) by the interaction of $Ba(ClO_3)_2$ & thallous sulfate. This compd is an oxidg agent which when heated forms thallic perchlorate

*Refs:* 1)Mellor **2**(1922), 355 2)Sidgwick, ChemElems **1**(1950), 487 3)Sax(1957), 1175

**o-Toluidine Chlorate,** $CH_3 \cdot C_6H_4 \cdot NH_2 + HClO_3$; mw 191.62, N 7.31%; col pltlts(from alc), mp explodes ca 88°; sol in w or alc; insol in eth or benz; was prepd by addg an aq soln of chloric acid dropwise to a sl excess of o -toluidine, care being taken not to add an excess of $HClO_3$ as the presence of a little free acid will decomp the mixt explosively, even at RT. This compd is not indefinitely stable in air, turning gray & finally blk on long standing. It burns explosively in contact with a flame

*Refs:* 1)Beil **12**,(374) 2)R.L.Datta & J.K. Choudhury, JACS **38**, 1080-81(1916)

**p-Toluidine Chlorate,** col crysts(from alc), mp expl at 125°; sol in alc; nearly insol in eth or benz; was prepd by addg an aq soln of $HClO_3$ dropwise to an ethereal soln of p-toluidine, taking care to keep the p-toluidine in sl excess. This compd on exposure to air gradually turns gray due to slow decompn of the salt. It takes fire suddenly in contact with a flame and emits a large amt of wh fumes

*Refs:* 1)Beilstein **12**,(411) 2)R.L.Datta & J.K.Choudhury, JACS **38**, 1081(1916)

**Trimethylsulfine Chlorate,** $S(CH_3)_3 \cdot ClO_3$; mw 160.63; col hygr crysts(from w), mp explodes at 170°; very sol in w; was prepd by double decompn of $AgClO_3$ & trimethylsulfine iodine, and evapg the soln on a w bath. This salt liquifies when exposed to air, and explodes violently on heating or in contact with a flame

*Refs:* 1)Beil **1**,(144) 2)R.L.Datta & J.K. Choudhury, JACS **38**, 1085(1916)

**Zinc Chlorate,** $ZnClO_3$; its prepn is given in Mellor(Ref 1) and in Gmelin(Ref 2)

*Dihydrate,* $Zn(ClO_3)_2 \cdot 2H_2O$; mw 268.27; col polyhedral crysts; can be obtd by allowing the tetrahydrate salt to stand at 65° for some time; its prepn is described in Gmelin(Ref 2).

*Tetrahydrate,* $Zn(ClO_3)_2 \cdot 4H_2O$; mw 304.36, col, deliq crysts, mp 55°, bp dec, d 2.15; can be obtd from the hexahydrate salt

*Hexahydrate,* $Zn(ClO_3)_2 \cdot 6H_2O$; mw 340.39; col monoclinic crysts, mp 60°, bp decomp; was prepd by action of chloric acid on zinc carbonate, by action of $Ba(ClO_3)_2$ on $ZnSO_4$, and by action of Zn fluosilicate on $KClO_3$. It gradually passes at 14-15° into the tetrahydrate salt

All of the zinc hydrated chlorates are very sol in w, alc, glycerin or ether. They, like other inorg chlorates, are also oxidizers which readily explode in contact with com-

bustible materials
*Uses:* In the book of Cundill(1889), available at PicArsn in the French translation [MP **5**, 333(1892)] is described an older expl *"Extralite(qv)"* which was based on Zn chlorate and AN

Ephraim & Jahnsen(See in Ref 2) prepd, by action of ammonia on zinc chlorate, two ammines which are expl: *Tetramminezinc(II) Chlorate,* $[Zn(NH_3)_4](ClO_3)_2$, col crysts; and *Hexamminezinc(II) Chlorate,* $[Zn(NH_3)_6](ClO_3)_2$, col crysts which lose $NH_3$ at RT and pass into the tetrammine deriv(See Vol 1, Table F,p A282)
*Refs:* 1)Mellor **2**(1922), 349-50 2)Gmelin, Syst Nr **32**(1924), 176 & **32**(1956), 882 3) Ullmann **3**(1929), 299 4)CondChemDict (1950), 714 5)Sidgwick, ChemElems **1**(1950), 277 6)Sax(1957), 1267

## CHLORATE EXPLOSIVES

**Chlorate Explosives** are mixts of chlorates (chiefly K or Na) with various combustible materials, such as oils, greases, paraffins, liquid nitrocompds, carbon, charcoal, etc. Many of these mixts are known and were used in Europe, since 1850's. Some of them, such as Cheddites, are still in use. Some of these expls, such as Rack-a-Rock, Rendrock & Vigorites were used in the US, but as far as is known, chlorate expls are not used now in the US, being replaced either by AN or perchlorate mixts
*Historical.* Since the discovery of potassium chlorate by C.L.Berthollet(in 1780's), attempts have been made to utilize it in expl mixts, chiefly as replacement for potassium nitrate in BkPdrs. K chlorate is not only a powerful oxidizer but it can also be detonated alone if allowed to fall, while in a molten state on a red-hot iron plate. The first expl utilizing K chlorate was prepd by Berthollet (See Berthollet Powder in Vol 2 of Encyclopedia , p B107-L). This was a much more powerful & brisant expl than BkPdr, but too dangerous to handle on acct of its extreme sensitiviness to friction and impact. This mixt often explod-ed during its manuf, or prematurely in firearms. After disastrous explns, which took place in France in 1788 and 1792 during pulverizing and mixing of ingredients(K chlorate, sulfur & carbon), the manuf of powders contg K chlorate was prohibited in France.

In the following 50-60 years K chlorate (or its substitute, Na chlorate) found no application in expls or proplnts but was used in percussion caps, where high sensitivity is a desirable property. One of the mixts suitable as a primer compn was Augendre Powder(See Vol 1 of Encyclopedia,p A507-L), proposed in 1849. This mixt was, however, too sensitive for use as an expl or a proplnt. In 1871, H.Sprengel of Germany partially solved the problem of densitization by adopting a method in which the chlorate was not brought into contact with combustible ingredients of intended mixts until ready to fire. He made up K chlorate into porous cartridges and then dipped them into liquid combustible materials just before use. These expls were, however, inconvenient to handle. The expls introduced in France in 1881 by E.Turpin under the name of "Poudres à double effet"( "Double Effect Powders"), which contained tar as a combustible and desensitizer, were more con-venient to handle and could be manufd before use. These expls, and later expls of Turpin (1888), known as "Pyrodialites" were not, however, as good as the expls patented in 1897 by Street, now known as Cheddites

Following is the list of chlorate expls which are or will be described in this Encyclopedia:
Alkalsit. See PATR **2510**(1958), Ger 3-R
Almatrites. See Vol 1,p A140-L
Asphalines. See Vol 1,p A496-L
Augendre Powder. See Vol 1,p A507-L
Azobenzene Cheddite Type Explosives. See Vol 1, A647-L
Bakufun. See Vol 2,p B5-L
Barbarit. See Vol 2,p B19-R
Baron & Cauvet Explosives. See Cauvet & Baron Explosives
Bayon Powder. See Vol 2,p B26-L
Bellford Powder. See Vol 2,p B32-R
Benedikt Explosives. See Vol 2,p B33-L
Bengaline. See Vol 2,p B33-R. This expl patented in 1882 by Mendail is erroneously called by Pérez Ara(Ref 15,p 211)"Benzalina"
Berthelot Powder. See Vol 2,p B106-L
Berthollet Powder. See Vol 2,p B107-L
Bjorkmann Explosives. See Vol 2,p B165-L
Boritines. See Vol 2,p B250-R & Ref 4,p 81
Brain Powders. See Vol 2,p B260-L & Ref 3,p 359
Brank(von) Powders. See Vol 2,p B261-L & Ref 20,p Ger 23
Briggs Explosive(1909). See Vol 2,p B265-L

Britainite. See Vol 2,p B300-R. A different compn:$KClO_3$ 72.0, AN 20.7 & naphthalene 7.3% is given in Ref 21,p 395
Brown's Powder. See Vol 2,p B 318-R
Callou Powder. Mixt of $KClO_3$ & $As_2S_3$ (orpiment). See Ref 3,p 262
Canouil Powder. See Vol 2,p C39-R; Ref 1a,p 303 & Ref 2, 108
Carlit(or Karitto) Explosive(1906). See Vol 2,p C68-R & Ref 21,p 399
Castan(Poudre végétale)(1884). See Vol 2,p C83-R; Ref 1a,p 305; Ref 2,p 782(as Végétale) & Ref 2,p 394
Casthelaz & Désignolle Powder(1867). See Vol 2,p C84-L; Ref 2,p 189(as Désignolle & Casthelaz) & Ref 21,p 392
Castro Powder(1884). See Vol 2,p C88-R; Ref 1a,p 305; Ref 2,p 118; Ref 15,p 213 & Ref 21,p 394
Catactine(or Chandelon) Explosives(1888). See Vol 2,p C88-R; Ref 1a,p 306; Ref 2,p 118; Ref 7,pp 695-6 & Ref 21,p 395
Cauvet & Baron Explosives. See Vol 2,p C91-R & Ref 21,p 394
Chakoor Powder(1903). See Vol 2,p C146 & Ref 21,p 398
Chandelon Explosives. See Catactine
Chapman Explosives(1888). See Vol 2,p C148; Ref 1a,p 306 & Ref 2,p 127
Chauvet Powders(1882). See Vol 2,p C 155 & Ref 21,p 394
Cheddites. See Vol 2,pp C 155
Chloratit. See Vol 2 & Ref 20,p Ger 28-L
Chlorat-Rivalit. See Vol 2 & Ref 8a,p 82 (under Rivalit)
Chloratzit. See Vol 2 & Ref 8a,p 21
Cicene. See Cycene
Clarite. See Vol 3 & Ref 2,p 143
Clement or Fuchs Powders. See Vol 3 & Ref 2,pp 145 & 310
Colliery Cheddite. See Note C in Table 3 under CHEDDITES
Colliery Steelite. See Vol 3 & Ref 5,p 383
Columbia Powder. See Vol 3 & Ref 21,p 395
Comet Powder. See Vol 3 & Ref 15,p 211
Cornet Powder. See Vol 3 & Ref 21,p 399
Coronite or Koronit. See Vol 3 & Ref 8a,p 55 & Ref 20,p Ger 32
Cotter Powder. See Vol 3 & Ref 21,p 399
CSE Explosives. See Vol 3 & Addnl Ref W,p 211(in this section)
Cycene(Cicene) Powder. See Vol 3 & Ref 21,p 395
Dapremont Powder(1877). See Ref 21,p 393
Davey Powders(1852). See Ref 1a,p 314; Ref 4,p 76 & Ref 21,p 393
Davies Powder(1860). See Ref 1a,p 315; Ref 2,p 180 & Ref 21,p 391
DeCustro Powders(1883). See Ref 1a,p 317 & Ref 2,p 183
Delhorbe Explosive. See Ref 2,p 184
Demetriade, Jonesen & William Explosive (1905). See Ref 21,p 398
Désignolle & Casthelaz Powder. See Casthelaz & Désignolle Powder
Dickson Powder(1895). See Ref 2,p 205
Distler, Blecher & Lopez Explosive. See Ref 7,p 259
Divine Explosives, such as Rack-a-Rock. See Ref 1a,p 76; Ref 2,p 667; Ref 3,p 265; Ref 5,p 379; Ref 7,p 135; Ref 15,pp 231-3 & Ref 21,p 393
Domergue Explosive(1889). See Ref 2,p 207 & Ref 21,p 395 Donar.
Donar. One of the expls patented in Russia by Fiedler. See Ref 2,p 300 & Ref 3,p 266
Double Effect Powders(of Turpin). See Ref 1b,pp 105-6 & Ref 2,pp 777-8
Dulitz Explosive(1886). See Ref 1a,p 323 & Ref 2,p 209
Duplexite(of Turpin). See Ref 1b,p 108; Ref 2,p 210; Ref 4,p 81 & Ref 21,p 395
Dynamogene(1882). See Ref 1a,p 327 & Ref 2,p 231
Edmunds Explosives(1893). See Ref 2,p 238
Egelit. Same as Miedziankit(Ref 8a,p 61)
Ehrhardt Powders(1864 & 1865). See Ref 1a,p 330; Ref 2,p 238; Ref 3,p 263 & Ref 15,p 214
Ennayaku. See Addnl Ref U,p 28( in this section)
Entoyaku. See Addnl Ref U,p 28(in this section)
Evangelidi Explosive(1904). See Ref 21,p 398
Explosifs O & OC. Same as Cheddites
Explosif O3. Same as Promethée
Explosif P. One of the Cheddites based on K chlorate(See Table 3, under CHEDDITES)
Explosif S. One of Cheddites based on Na chlorate(See Table 3 under CHEDDITES)
Explosive Papers(Papiers explosibles in Fr). See Ref 1b,pp 62-4; Ref 2,pp 436,599,604 & 665 and Ref 15,p 213
Extralite. See Ref 1a,p 333
Fahrm Explosive(1898). See Ref 2,p 294
Fallenstein Explosive(1884 & 1886). See Ref 1a,p 334 and Kinetite
Fenton Powder(1873). See Ref 1,p 335; Ref 2,p 298; Ref 3,p 264; Ref 15,p 212 & Ref 21,p 392
Fielder Explosives(1901). See Ref 2,p 300; Ref 3,p 266 & Ref 15,p 231 and also Donar

Flerlet Powder(1870). See Ref 21,p 392
Flobert Ammunition. See Ref 8a,p 40
Fluorine of Turpin. See Ref 2,p 302
Fontaine Powder(1896). See Ref 1a,p 336; Ref 2,p 616(under Picrates) & Ref 21,p 397
Fontana, Barelly & DeChoisy Powder(1869). See Ref 21,p 392
Fränkel Explosive. See Ref 1a,p 338 & Ref 2,p 309
Fuchs(or Fux) Powder. See Ref 1a,p 339; Ref 2,pp 145 & 310; Ref 21,p 399
Gelatin-Cheddites. See Table 4 under CHEDDITES
German Chlorate Explosives. See Ref 20,pp Ger 3,23,28,32 & 69
German Chlorate Primary Mixtures. See Ref 20,p Ger 136
German Chlorate Pyrotechnic Mixtures. See Ref 20,p Ger 154
Gerresdorfer & Bals Powder(1892). See Ref 2,p 341 & Ref 21,p 395
Gesteins-Koronit. See Ref 14,p 364 & Ref 20,p Ger 69 & table 22
Giedyuim Powder(1868). See Ref 21,p 392
Girard Explosives(1900, 1905 & 1908). See Ref 2,p 343; Ref 4,pp 93 & 95; Ref 21,pp 396-7 & 399
Goetz Powder. See Ref 1a,p 349; Ref 2,p 355 & Ref 21,p 400
Golovine Explosive(1905). See Ref 21,p 398
Gomez Powders. See Ref 1a,p 350; Ref 2,p 356 & Ref 21,p 400
Gotham Explosive. See Ref 1a,p 350; Ref 2,p 356 & Ref 21,p 400
Grafitite or Graphitite(1896). See Ref 21,p 396
Graham Powder. See Ref 1a,p 351; Ref 2,p 356; Ref 15,p 212 & Ref 21,p 400
Green Powder(1887).(Poudre verte in Fr). See Ref 1b,p 110; Ref 2,p 784; Ref 15,p 222 & Ref 21,p 396
Hafenegger Powders(1868). See Ref 1b,p 7; Ref 2,p 366; Ref 3,p 263 & Ref 21,p 392
Hahn Powders(1867). See Ref 1b,p 8; Ref 2,p 366; Ref 3,p 264 & Ref 15,p 206
Hall(or Will) Powder(1863). See Ref 1b,p 8; Ref 2,p 366 & Ref 21,p 391
Hannan Explosives(1882). See Ref 1b,p 9; Ref 2,p 368 & Ref 21,p 391
Harrison Powders(1862). See Ref 1b,pp 9-10; Ref 2,p 369 & Ref 21,p 391
Hart Powder(1888). See Ref 1b,p 10 & Ref 2,p 369
Harvey Explosive. See Ref 2,p 369 & Ref 21,p 400
Hassia-Chlorat. See Ref 8a,p 48
Hawkins Explosive(1895). See Ref 2,p 370
Hawkins Brothers Explosives(1896). See Ref 2,p 370 & Ref 21,p 391
Hercules Dynamite. See Ref 1b,p 12 & Ref 2,p 374
Himalaya Powder or Himalayite(1906). See Ref 8a,p 51 & Ref 21,p 399
Himly Powder. See Ref 2,p 375; Ref 15,p 216 & Ref 21,p 400
Himly and Von Trütschler-Falkenstein Powder (1869). See Ref 2,p 375
Hochstätter Powder(1869), See Ref 1b,p 14; Ref 2,p 376 & Ref 21,p 392
Horsley Dynamites(1872). See Ref 1b,p 14 & Ref 2,p 712
Horsley Powder. See Ref 21,p 392
Howittite. See Ref 1b,p 15 & Ref 2,p 372
Ievler(or Jewler) Explosives(1897), such as Promethée or Explosif 03. See Ref 2,p 382 & Ref 15,p 231
Jahnite(or Jahline). See Johnite
Jewler Explosives. See Ievler Explosives
Johnite Explosive. See Ref 1b,p 16 & Ref 2,pp 387-8
Justice Powders(1888). See Ref 1b,p 19; Ref 2,p 389 & Ref 21,p 394
Keil Explosive. See Ref 1b,p 19 & Ref 2,p 391
Kellow & Short Powder(1862). See Ref 1b,p 20; Ref 2,p 391; Ref 3,p 262 & Ref 21,p 391
Kieselbacher Chloratsprengstoff. Same as Miedziankit(Ref 8a,p 61)
Kinetite Explosive(1884). See W.Smith JSCI 6, 2-12(1887). Ref 1b,pp 20-1; Ref 2,p 392; Ref 4,p 186 & Ref 15,p 210
Kirsanow Explosive(1901). See Ref 3,p 231 & Ref 21,p 397
Kiwit. See Ref 8a,p 54
Knaffl Powder. See Ref 1b,p 21; Ref 2,p 293; Ref 3,p 263; Ref 15,p 214 & Ref 21,p 400 (spelled Knaffi)
Köhler Powder(1857). See Ref 1b,p 22; Ref 2,p 393 & Ref 15,p 206
Kolbe Explosive. See Ref 1b,p 22 & Ref 2,p 393
Kolowratnik Explosive No 3(1912). See Ref 7,p 325
Köpe(Moritz) Explosive(1883). See Ref 15,pp 215-16
Koronit. See Ref 20,p Ger 102
Kraft Dynamite of Bjorkmann. See Ref 1b,p 23 & Ref 2,p 396
Landauer Explosives, known also as Landin or Launoy(1891). See Ref 1b,p 25; Ref 2,pp

402-3 & Ref 21,p 395
Landin. See Landauer Explosives
Lascinski Explosive(1906). See Ref 21,p 399
Launoy. See Landauer Explosives
L.C.Pulver. A Ger Cheddite(Ref 8a,p 56)
Le Maréchal Powder(1885). See Ref 1b,pp 26-7; Ref 2,p 404; Ref 3,p 266 & Ref 21,p 394
Lheure Explosive(1905). See Ref 21,p 398
Liardet Explosive(1893). See Ref 7,p 699
Lindeman Explosive(1899). See Ref 2,p 408
Lindner Explosive(1895). See Ref 2,p 409
Louis Explosives(1905). See Ref 4,p 100
Mackintosh Powder(1857). See Ref 1b,p 31
Mathews Powder(1905). See Ref 21,p 398
Maurette Powder. See Ref 2,p 420
Melland Explosive Paper(1865). See Ref 1b,pp 36-7; Ref 2,p 436; Ref 3,p 265; Ref 15,p 216 & Ref 21,p 391
Melville Powders(1850). See Ref 1b,p 37; Ref 2,p 436; Ref 15,p 212 & Ref 21,p 391
Mendail Explosive. See Bengaline in Vol2,p B 33-R. It is called Benzalina in Ref 15,p 211
Mercurit. See Ref 8a,p 60
Michailowski Powder(1882). See Ref 1b,p 39; Ref 2,p 439 & Ref 21,p 394
Miedziankit(Egelit or Kieselbacher Chloratsprengstoff). See Table 3, Note D under CHEDDITES
Millbank Explosives. See Ref 1b,p 39 & Ref 2,p 439
Minélite(1911). See Ref 14,p 360; Ref 15,p 210 & Ref 21,p 399
Minélites A, B & C. See Note C, Table 2 under CHEDDITES
Minnensprengstoff. See Table 3 under CHEDDITES
Mitchellite. See Ref 8a,p 62
Monnier Powder. See Ref 1b,p 41; Ref 2,p 442 & Ref 21,p 400
Mundell Powder. Same compn as Pertuiset
Naphthalite. See Ref 8a,p 65
Nightingale & Pearson Explosive(1897). See Ref 2,p 452 & Ref 15,p 212
Nisser Powders(1865-1870). See Ref 1b,pp 43-4; Ref 2,p 452; Ref 3,p 265; Ref 15,p 215 & Ref 21,p 392
Nitrocaillebotte(or Nitrocurds) Explosive of Sjöberg(1886-7). See Ref 1b,pp 47 & 95 and Ref 2,p 493 & 717
Nitrolkrut(1876). See Ref 1b,p 49; Ref 2,p 560 & Ref 21,p 53
Nobel Explosive(ca 1880). See Ref 1b,p 53 & Ref 2,p 577
Nobel Safety Explosive(1896). See Ref 2,p 580 & Ref 21,p 396
Noble Powders(1880). See Ref 1b,p 57; Ref 2,pp 582-3 & Ref 21,p 393
Nysebastine(1876). See Ref 2,p 586
Oliver Powder(1869). See Ref 1b,p 59; Ref 2,p 590 & Ref 21,p 392(spelled Olivier)
Oriental Powder. See Ref 1b,p 59 & Ref 2,p 591
Papier explosible. See Explosive Paper
Parone Explosive. See Ref 1b,p 63; Ref 2,p 601 & Ref 15,p 206
Pattison Explosive(1880). See Ref 1b,p 63; Ref 2,p 601 & Ref 21,p 393
Peck Powder(1905). See Ref 21,p 398
Pelez(or Peley ?) Explosive Paper. See under Explosive Papers
Pellier Powders(1882 & 1884). See Ref 1b,pp 65-6; Ref 2,p 603; Ref 15,p 216 & Ref 21,p 394
Perkins Primary Mixtures(1870). See Ref 1b,p 66; Ref 2,p 609
Perlit. See Dr. Roman, NC **3**, 161(1932)
Permanit. See Dr. Roman, NC **3**, 161(1932)
Pertuiset(or Mundell) Powder(1867). See Ref 1b,p 66; Ref 2,pp 447 & 610; Ref 15,p 206 & Ref 21,p 392
Petrofracteur Explosive. See Ref 1b,p 67 & Ref 2,p 613
Petrolit. See Ref 8a,p 74
Petry Explosive Card(1882). See Ref 21,p 394
Pettinger Primary Mixtures(1898). See Ref 2,p 614
Pierrite Explosive. See Ref 8a,p 74
Pirodialiti. See Pyrodialites of Turpin
Pirodialiti senza fiamma. See Ref 21,p 396
Pironome. See Pyronome
Plastigels. See Table 4 under CHEDDITES
Plessit. See Ref 8a,p 76
Pohl White Powder. See Ref 1b,p 69; Ref 2,p 635; Ref 5,p 576 & Ref 15,p 212
Pollard Powder. See Ref 2,p 635 & Ref 21,p 400
Poudre blanche Cornil. See Cornil White Powder
Poudre végétale. See Castan(Poudre végétale)
Promethée or Prometheus Explosive(1900). See Ref 2,p 382; Ref 3,p 266; Ref 8a,p 77; Ref 15,p 231 & Ref 21,p 397
Prussian Fire. See Wigfall Powder
Pyrodialites(of Turpin)(1888-1898). See Ref 2,pp 661-4; Ref 3,p 266; Ref 4,p 108 & 147; Ref 5,p 379 Ref 14,p 360 & Ref 21,p 396(Pirodialiti)(See also Double-Effect Powders)

Pyrodialites, Flameless. See Pirodialiti senza fiamma in Ref 21,p 396
Pyronome(1881). See Ref 1b,p 74; Ref 2,p 664 & Ref 21,p 393
Quinby, Sharps & Gregro Explosive(1902). See Ref 21,p 397
Rack-a-Rock(1881). See Ref 1b,p 76; Ref 2,pp 667-8; Ref 3,p 265; Ref 5,p 379; Ref 7,p 135; Ref 8a,p 79; Ref 15,pp 231-3 & Ref 21,p 393
Raibun. See Addnl Ref U,p 25(in this section)
Randites(1892). See Ref 2,p 668 & Ref 21,p 395
Rave Explosives(1859). See Ref 1b,pp 76-7; Ref 2,p 669 & Ref 21,p 391
Rendrock Powder Co Explosives(1881, 1901 & 1904). See Ref 21,pp 393, 397 & 398
Reverley Powder(similar to Augendre Powder). See Ref 1b,p 79; Ref 2,p 681; Ref 5,p 377 & Ref 21,p 400
Reynolds Powder. See Ref 1b,p 79; Ref 2,p 681 & Ref 21,p 400
Ricker & Spence Powder(1862). See Ref 1b,p 80; Ref 2,p 683; Ref 15,p 214 & Ref 21,p 391
Robert Powder(1873). See Ref 1b,p 81 & Ref 2,p 686
Robertson Powder. See Ref 1b,p 82 & Ref 2,p 686
Roger Powder(1870). See Ref 1b,p 84; Ref 2,p 691; Ref 15,p 206 & Ref 21,p 392
Romite(1882). See Ref 1b,p 84; Ref 2,p 691; Ref 15,p 206 & Ref 21,p 394
Rompe-roca. A Cuban expl similar to Rack-a-Rock. See Ref 15,p 233
Ross & Cairney Explosives(1899). Ref 2,p 693 & Ref 21,p 396(spelled as Roos
Rudeloff Plastic Explosives(1906). See Ref 7,p 246
Sanlaville & Laligant Powder(1880). See Ref 1b,p 87; Ref 2,p 700 & Ref 21,p 393
Schindler Powder(1893). See Ref 2,p 703 & Ref 21,p 395
Schlesinger Powder(1852). See Ref 1b,pp 89-90 & Ref 2,p 703
Schnebelin(or Schnebelite) Powder(1891). See Ref 1b,p 90; Ref 2,p 703 & Ref 21,p 393
Schnebelin-Boileau Powder(1902). See Ref 21,p 397
Schückher Powders(1890). See Ref 1b,pp 90-1 & Ref 2,pp 704-5
Schuler Powder(1893). See Ref 2,p 705; Ref 15,p 212 & Ref 21,p 395
Sebomite(1904). See Ref 3,p 266; Ref 4,p 148; Ref 8a,p 88; Ref 14,p 360 & Ref 21,p 398
Sederolite Primary Mixture. See Ref 1b,p 93; Ref 2,p 712 & Ref 21,p 400
Seranine of Horsley. See Ref 1b,p 94; Ref 2,p 713 & Ref 21,p 400
Sharp & Smith Powder(1866). See Ref 1b,p 94; Ref 2,p 714; Ref 3,p 264; Ref 15,p 215 & Ref 21,p 391
Siemens Powder(1882). See Ref 1b,p 94; Ref 2,p 715; Ref 3,p 264; Ref 15,p 206 & Ref 21,p 394
Silberrad Powder(1911). See Ref 7,pp 675-6
Silesia Powders. See Ref 3,pp 185-6; Ref 5,pp 382-3; Ref 7,p 151; Ref 8a,p 89; Ref 14,p 360; Ref 15,pp 209-10 & Ref 21,p 400
Silesite Powder of Pietrowicz & Sieger(1889). See Ref 1b,p 95; Ref 2,p 714 & Ref 3,p 81
Simpson Powder(1904). See Ref 21,p 398
Singleton Powder(1898). See Ref 2,p 717 & Ref 21,p 396
Sjöberg Explosive(1886-7). See Nitrocaillebotte
Slack Powder(1898). See Ref 2,p 717 & Ref 21,p 396
Sleeper Powder. See Ref 1b,p 96 & Ref 2,p 717
Smith Explosive(1905). See Ref 21,p 398
"Société Universelle d'Explosifs" Explosives (1911). See Ref 7,pp 681-2
Sodalite Explosive(1897). See Ref 2,p 721 & Ref 21,p 396
Spence Powder. See Ref 2,p 735; Ref 3,p 263 & Ref 15,p 214(See also Ricker & Spence Powder)
Spore Explosive(1903). See Ref 21,p 397
Sprengel Type Chlorate Explosives. See Ref 3,p 268; Ref 8a,pp 90-1 & Ref 15,p 230
Stanley Explosive(1905). See Ref 21,p 398
Steele Explosive(1904). See Ref 21,p 398
Steelite(1907). See Ref 4,p 148; Ref 5,p 382; Ref 8a,p 91; Ref 14,p 360 & Ref 15,p 209
Stockholms Superfosfat Fabriks AB Explosives (1915). See Ref 7,p 741
Storite Explosives(1893). See Ref 2,p 739 & Ref 21,p 400
Street Explosives or Streetites. Same as Cheddites
Stubenrauch's Explosive(1896). See Ref 2,p 795(as Von Stubenrauch)
Styre Powder(1900). See Ref 21,p 397
Teutonite. A modification of Augendre Powder. See Ref 2,pp 74 & 765
Thomas Explosive(1905). See Ref 21,p 398
Thorite Powder(1895). See Ref 2,p 766 & Ref 21,p 395

Thunder Powder. See Ref 1b,p 103 & Ref 2,p 767
Trobach Primary Mixture(1890). See Ref 2,p 776
Tschirner Explosive(1880). See Ref 1b,p 105; Ref 2,p 777; Ref 7,pp 693-4; Ref 15,p 222 & Ref 21,p 393
Turpin Explosives Containing Chlorates. See Boritines, Double Effect Powders, Duplexite, Fluorine, Pyrodyalites and "un-named" expls listed in Ref 1b,p 108
Un-named-chlorate explosives of Turpin. See Ref 1b,p 108
US Naval Friction Fuse Composition (obsolete). See Ref 2,p 779
"Végétale" Powder of Castan(1884). See Castan(Poudre végétale)
Velterine C or Welterine C(1893-1897). See Ref 2,p 783 & Ref 7,p 35
Venghöffer Powder(1889). See Ref 21,p 395
Vergé Explosive(1903). See Ref 21,p 397
Verte(Poudre). See Green Powder
Victorite(1887). See Ref 1b,p 110; Ref 2,p 785; Ref 7,p 323 & Ref 15,p 222
Vigorine of Bjorkmann(1875), also called (incorrectly accdg to Salvati) Vigorite. See Ref 2,p 785 and Ref 21,pp 387 & 392
Vigorite of California Vigorite Powder Co. See Ref 1b,p 111 & Ref 2,p 786
Vigorite of Hamilton Powder Co. See Ref 1b,pp 110-11; Ref 2,p 786 & Ref 8a,pp 100-1
Vigorite of Nordenfeldt. See Ref 3,p 362
Von Brank's Powders. See Brank's Powders in Vol 2 of Encyclopedia or in Ref 2,p 790
Von Stubenrauch's Explosives. See Stubenrauch's Explosives
Von Wendland's Explosive. See Wendland's Explosive
Vril Explosives(1889). See Ref 1b,p 113; Ref 2,p 797; Ref 3,p 264; Ref 4,p 81 & Ref 21,p 395
Vulcaïne Explosive(1893). See Ref 2,p 797
Vulcan Powder(Poudre vulcain in Fr). See Ref 1b,p 113 & Ref 2,p 797
Vulcanite of Moritz & Köppel(Austria). See Ref 1b,p 114 & Ref 2,p 798
Wahlenberg Explosives(1876). See Ref 1b,p 115; Ref 2,p 800; Ref 15,p 230(spelled Walenberg) & Ref 21,p 392
Ward & Gregory Powder. See Ref 21,p 400
Ward & Gregory Primary Mixture. See Ref 2,p 802
Weber Powder. See Ref 2,p 803
Wendland's Explosive(1886). See Ref 2,p 796 & Ref 21,p 394
White Powder. See Augendre Powder
Wigfall Powder or Prussian Fire( Feu prussien in Fr). See Ref 2,p 809 & Ref 21,p 391
Wilhelmit. See Ref 8a,p 103
William Powder. See Ref 1b,p 118 & Ref 2,p 810
Winiwarter Primary Mixture(1852 & 1853). See Ref 1b,p 118 & Ref 2,p 810
Zaliwsky Powder. See Ref 1b,p 120-1 & Ref 2,p 814

Some chlorate mixts which bear no names are listed under Addnl Refs , which follow

*Properties of Chlorate Explosives.* In general, expls based on chlorates are very powerful and brisant, but are very sensitive to friction and impact. Coating of particles of chlorates with substances such as castor oil, rosin, paraffin, tar, aromatic nitrocompds, crude rubber, vaselin, pertoleum, plastic materials, diminish considerably the sensitiveness but not sufficiently to make these expls suitable for loading artillery shells(See CHEDDITES)

The chlorate expls are more sensitive than those contg perchlorates, and expls contg Na chlorate are more sensitive than those with K chlorate. Expls contg K or Na chlorate should not be mixed with Amm salts because, in this case, double decomp takes place with the formation of Amm chlorate which can explode spontaneously. It also is advisable not to use either PA or TNCrs in chlorate expls, because such mixts are very sensitive(Ref 7,p 383). These precautions were not always followed
(See also under individual chlorate expls, such as CHEDDITES)

*Uses of Chlorate Explosives.* Most chlorate expls have been used for industrial purposes, but during WWI & WWII some were used by the French, Russians, Italians, Japanese and Germans for loading mines, torpedoes, hand grenades & depth charges(but not in artillery shells). Many expls contg chlorate have been used in primers and detonators
(See also under individual expls, such as CHEDDITES)

*Refs:* 1a)Cundill(1889) in MP **5**(1892) 1b) Cundill(1889) in MP **6**(1893) 2)Daniel(1902), various pages 3)Gody(1907), 262-70 4) Escales, Chloratspr(1910), 76-100(List of patents from 1849 to 1909); 143-6(Compns &

props of chlorate expls used ca 1910) 5) Marshall **1**(1917), 377-82 6)Marshall **2**(1917), 759 7)Colver(1918), 135,159,167,246-7, 278,323,325,351,673,675-6,681-2,693-6,699 & 741 8)Barnett(1919), 106-13 8a)Marshall, Dict(1920), various papes 9)Naoům, NG (1928), 427-30 10)Vennin, Burlot & Lécorché (1932), 537-44 11)Marshall **3**(1932), 111-13 12)Stettbacher(1933), 309-15 13)Pepin Lehalleur(1935), 344-50 13a)I.F.Blinov, "Khloratnyiye i Perkhloratnyiye Vzryvchatyiye Veshchestva"(Chlorate and Perchlorate Explosives), Oborongiz, Moscow(1941) 14) Davis(1943), 357-63 15)Pérez Ara(1945) 199-261, 222 & 230-32 16)Vivas, Feigenspan & Ladreda **2**(1946), 347 & 349 17)Stettbacher (1948), 90-1 18)Belgrano(1952), 179-81 19)Stettbacher(1952), 117-19 20)PATR **2510** (PB 161270)(1958),pp Ger 3,23,28,32,69,136 & 154 21)Giua, Trattato **6**(1959, 390-400 22)I.Huhtanen, Explosivst **1960**, 189-94 (Chlorate expls used in Finland) 23)F.A. Warren et al,"Chlorates and Perchlorates, Their Manufacture, Properties and Uses", NAVORD Rept **7147**(Vol 1)(1960), 195-208 24)Ibid, Vol 2(1960)(Conf)(not used as a source of info)

*Addnl Refs:* A)Sprengstoff AG Carbonit,GerP 307880(1917)(not found in CA or in JSCI) (Expls prepd by fusing chlorates with urea or other substances capable of forming easily fusable masses) B)J.Baumann, ChemZtg **44**, 474(1920) & CA **14**, 2712(1920)(Chlorate expls contg dicyandiamide) C)E.Wolcott, USP 1355203(1920) & CA **15**, 177(1921) (Desensitized K chlorate suitable for use in expl compns can be prepd by crystn from an aq soln of chlorate and sulfonated derivs of California pertoleum) D)B.Mühlefeld, SS **16**, 113-15(1921) & CA **16**, 496(1922)(Description of chlorate expls used in Germany for blasting rocks of medium hardness and in potash, rock salt & iron ore mining) E)E.Spitalsky & E. Krause, SS **20**, 103-7, 119-23 & 133-5(1925) & CA **20**, 1141(1926)(Description of chlorate expls used in Russia) F)A.C.Scott & Mexco, Ltd, BritP 248089(1926) & CA **21**, 652(1927) (Crysts of O-carrying substs, such as K chlorate are coated with synthetic resin such as may be formed from a phenol, a phenol & formaldehyde, or from urea or thiourea. Other ingredients such as MNN, DNT, a perchlorate or woodmeal may be added) G)Dr. Roman, NC **3**, 161-3(1932)(Compn & props of some chlorate & perchlorate expls) H)P.Bjørkman, TekTidUpplCKemi **64**, 41-4(1934) & CA **28**, 6311-12(1934)(Claims that expls prepd by impregnating porous K chlorate briquets or grains with liq hydrocarbons are less sensitive to friction than ordinary K chlorate expls) I)G. von Feilitzen, Ibid(Claims that B's expls are sensitive to friction; several accidents with these expls are cited) J) I.G.Farbenind AG, USP 2000414(1934) & CA **29**, 4180(1935)(Claims that incorporation of Amm chlorate, up to 20%, in Na nitrate expls increases their brisance without increasing their sensitivity to friction) K)I.F.Blinov, ZhPriklKhim **8**, 52-5(1935) & CA **29**, 7077 (1935)[Impact test values were detd for the following types of chlorate expls: a)92ps of K chlorate(grain size 0.15mm) mixed with 8ps of liq desensitizer(such as kerosene, xylene, glycerin, castor oil, MNT, aniline or benzene) and b)K chlorate 85ps mixed with 15ps of a solid or semi-solid desensitizer(such as rosin, MNN, petroleum bottoms, naphthalene, paraffin or petrolatum). Results of tests have shown that with the liquids, the sensitivity depends mainly on their chem structure(aromatic compds showed the highest desensitizing props), while the viscosity was of secondary importance. As to the solid- or semi-solid ingredients, their desensitizing props depend not only on their compn, but also on the plasticity) L)L.S.Beyers, USP 2079105(1937) & CA **31**, 4500(1937)[Blasting expls contg 66-73ps of a mixt of alkali chlorate & alkali nitrate together with 17-20ps of liq DNT(fr p 3-15°) and 10-14% of a 20-60 mesh woodmeal] M)L.S.Beyers, USP 2083143(1937) & CA **31**, 5583(1937)[An expl suitable for blasting: K chlorate 38-41, Na nitrate 19-23, shredded wood 13-14, liq DNT(frp -5-+15°) 23.5-27.5 & NC(N>12%) 0.5-2.5%. Method of prepn is described] N)I.F.Blinov, Kalii(Russia), **1937**, No 10, 19-31 & CA **33**, 3155-6(1939) (Compn & props of some Rus chlorate expls of weak & medium strength used in open or underground work) O)C.O.Davis, USP 2190703(1940) & CA **34**, 4270-1(1940)(Expls prepd by dispersing a solid "O-accepting" ingredient, such as Al, ferro-Si, S, sugar, nitrocompd, etc with a chlorate or perchlorate dispersed in anhydrous ammonia) P)D.C. McMeans, USP 2109049(1938) & CA **32**, 3156 (1938)[Granular chlorate expl suitable for underground work is prepd by mixing $KClO_3$

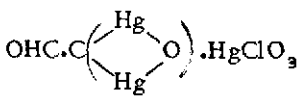
35, a "hot mixture" 20(obtained by heating 12ps of liq DNT, 6ps of toluene & 2ps of petrolatum with a small amt of nitric acid until disappearance of N oxides fumes), sugar 35 & sawdust 10%] Q)E.Lorenzini, BritP 535971(1941) & CA **36**, 1496(1942) [Expl compns prepd by mixing solns(in w or in other suitable solvents) of inorg or org chlorates and/or perchlorates with binding substances, such as dextrin, starch or gum arabic, followed by incorporation of combustibles such as cellulose, coal dust, sulfur, etc, which were previously stirred with w. The resulting slurry is then concentrated into a paste and mixed with a stabilizing oily subst, such as vaselin, paraffin, or castor oil) R)J. Billwiller, FrP 862323(1941) & CA **42**, 9179-80 (1948) [Expls obtained by mixing Amm chlorate (nitrate or perchlorate) with naphthalene, paraffin, lubricating oil, etc can be exploded in a closed space by a compn such as thermite) S)W.R.Tomlinson, Jr, PATR **1230**(1943) (Investigation of two chlorate expls of the Universal Powder Co showed that these expls offered no promise for use in military ammo or in demolition work) T)A.J.Phillips, PATR **1277**(1943)(Study of Na chlorate expls of Kiernan & Bowen showed that these expls offered no promise for use in military ammo or in demolition work) U)Anon, "Handbook of Japanese Explosive Ordnance", OpNav **30-3M**(1945), 25-32(Compns of Jap chlorate expls: Bakufun, Ennayaku, Entoyaku & Raibun) V)G.C.Tibbits et al, PB Rept **50394**(1946),p 91(Japanese used during WWII, quite extensively, mixts contg chlorates or perchlorates, both for industrial and military purposes, such as in blasting, demolition work, mines and depth charges) W)L.Médard, MP **35**, 210-14 & 218(1950)(Chlorate expls developed after WWII by the Commission des Substances Explosives) X)S.Custodero, ItalP 522944 (1955) & CA **53**, 3698(1959)(Expls prepd by incorporating an oxidizer, such as a chlorate or a perchlorate into a liquid polymer, which is then solidified by addn of a suitable catalyst) Y)I.Huhtanen, Explosivst **1960**, 189-94(Some chlorate expls used in Finland)

**Chloratit.** A type of Austrian and Ger chlorate expl, consisting of Na or K chlorate & hydrocarbons in a variety of compns, which was sanctioned for blasting operations during and after WWI. Some chloratit compns & their props are given by Fedoroff et al in PATR **2510** (1958),p Ger 28. See also A.Haid & H.Selle, SS 251-2(1929) & Pepin Lehalleur(1935), 347

**Chlorat-Rivalit.** A Ger expl introduced during WWI: K chlorate 88.5 & paraffin 11.5%
*Ref:* Marshall, Dict(1920), 82

**Chloratzit.** A Ger expl contg K chlorate & perchlorate together with aromatic nitrocompds, resins and carbohydrates. Cooling agents were incorporated for mixts intended for use in coal mines, and the name was changed to Kohlen- or Wetter- Chloratzit
*Ref:* Marshall, Dict(1920), 21

**Chloratodimercuriacetaldehyde or Chloratodimercuraldehyde,** $OHC.C(:Hg).HgClO_3$; mw 625.66, col, lustrous prisms, exceddingly expl even when covered with w; was obtd by adding alc acetaldehyde to a soln of mercuric oxide in aq $HClO_3$. It explodes violently just by shaking even under water
*Refs:* 1)Beil **3**, 606(Under Oxydimercuriacetaldehyd) 2)K.A.Hofmann, Ber **38**, 2000(1905)

**Chloratotrimercuriacetaldehyde or Chloratotrimercuraldehyde,** 

mw 742.25; wh pdr, explodes on contact with a flame or concd sulfuric acid; can be prepd by passing acetylene into an aq soln of mercuric chlorate or into a mixt of mercuric nitrate and Na chlorate. It is sl less expl than the dimercuric compd above.

Wohler & Matter(Ref 3) give the following expl props: *Expln Temp* 130° (in 20 secs)(See also Ref 4) and *Lead Block Expansion* at d 2.995 15.3cc vs 25.6 at d 3.368 for MF
*Refs:* 1)Beil **3**, 607 {Under Tris-[hydroxymercuri] -acetaldehyd} 2)K.A.Hofmann, Ber **38**, 2001 (1905) 3)L.Wöhler & O.Matter, SS **2**, 204-5 & 247(1907) 4)Davis(1943), 411

**Chloric Acid,** $HClO_3$; mw 84.47, exists only in aq solns, the highest concn of which corresponds to the *hepta*- hydrate, $HClO_3.7H_2O$; mw 210.58. Its solns(up to 40%), are colorless, frp <-20°, bp dec 40°, d 1.282 at 14.2°; toxic rating is given in Sax(Ref 7). Its usual method of prepn is to treat an aq suspension of Ba chlorate with an equiv amt of dil $H_2SO_4$; after filtering the $BaSO_4$, the col filtrate is concd in vacuo at

10-20° over concd $H_2SO_4$ to a d of 1.26. This corresponds to a 40% soln; attempts to prep stronger solns always resulted in decompn

Solns up to 30% strength are fairly stable when stored in the cold, away from light, and provided org matter is absent. Concd solns of $HClO_3$ are dangerous to store because on standing they form chlorine dioxide(qv), $ClO_2$, one of the most powerful oxidg agents. When aq solns are warmed, chlorine & $ClO_2$ may evolve depending upon the concn

Chloric acid is strongly ionized in w and in some org solvs. It is a strong oxidg agent reacting with reducing compns. such as metals or org compds, sometimes violently(Ref 4). Wood, paper & similar materials decomp the acid at once, very often with spontaneous combustion or even a mild explosion.

The salts of chloric acid, called *Chlorates* (qv), are important compds in the expl, proplnt & pyrotechnic industries

*Refs:* 1)Mellor **2**(1922), 269 & 305 2)Gmelin, Syst Nr **6**(1927), 307 3)Mellor(1939), 515 4)V.Majer, Chemie(Prague) **3**, 90-1(1948) & CA **46**, 2805(1952)(Explosion produced by $HClO_3$) 5)Kirk & Othmer **3**(1949), 707 6) Ullmann **5**(1954), 525-6 7)Sax(1957), 461

## TABLE IX

### Types, Grain Dimensions, Weights of Charges and Other Data for Propellants Used in US Army Artillery Ammunition (Except Rockets)

*(Information for this table was supplied by Russell L. Trask and J. F. W. Pflueger of Picatinny Arsenal)*

| Model, Type and Granulation of Propellant | Weight of Propellant Charge In ounces | Chamber Pressure, psi (Copper gage) | Grain Dimensions in inches L | D | d | W | $W_o$ | $W_f$ | $W_a$ | Ratio L/D | Ratio D/d | Difference: $\frac{(W_o - W_f) \times 100}{W_o}$ | Type of Ammunition | Type, Mode and Weight o Projectile, l |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IMR 7005;(SB w DNT coating); SP | 1.29 | 55300 | 0.0845 | 0.0542 | 0.0113 | 0.0215 | – | – | – | 1.56 | 4.80 | – | FA | Ctge, Ball, M55 (0.217) |
| Ball, WC870 | 1.38 | 52000 | *Granulation* (percent retained on US Sieves): 0.00% on No 16; 0.13 on 18; 7.93 on 20; 42.08 on 25; 48.38 on 30; 0.67 on 35 and 0.49% on No 40 | | | | | | | | | | FA | Ctge, Ball, M55 (0.217) |
| M2; (DB); SP | 4.50 | 30000 | 0.2405 | 0.0617 | 0.0073 | 0.0272 | – | – | – | 3.90 | 8.45 | – | FA | Pract, M55A1 (1 |
| M1; (SB w DNT); SP | 10.48 | 40000 | 0.2770 | 0.1221 | 0.0143 | – | 0.0210 | 0.0186 | 0.0198 | 2.27 | 8.54 | 12.12 | FA | AP, M87A1 (1.9 |
| M10; (SB); SP | 13.95 | 5300 | 0.1351 | 0.0492 | 0.0134 | 0.0179 | – | – | – | 2.75 | 3.67 | – | FA | HE, M306A1 (2. |
| M8; (DB); Sheet (Four increments) | 0.364 | – | 1" × 1" × 0.004" | | – | – | – | – | – | – | – | – | MA | HE, M49A2 (3.0 |
| M9; (DB); Discs in Ignition Ctge M5A1 | 0.091 | – | 0.0031 | 0.0345 | – | – | – | – | – | – | – | – | MA | HE, M49A2 (3.0 |
| M10; (SB); MP | 52.97 | 6800 | 0.4587 | 0.1963 | 0.0203 | – | 0.0335 | 0.0341 | 0.0338 | 2.34 | 9.67 | −1.78 | FA | HE, M309A1 (14 |
| M1; (SB w DNT) SP | 17.03 | 33500 | 0.2828 | 0.0476 | 0.0184 | 0.0146 | – | – | – | 5.94 | 2.59 | – | FA | HE, M48 (14.70) |
| M1; (SB w DNT); SP | 5.82(Z1)<br>7.48(Z2)<br>9.66(Z3)<br>14.55(Z4) | 5400<br>6200<br>10300<br>25500 | 0.2798 | 0.0567 | 0.0188 | 0.0189 | – | – | – | 4.93 | 3.02 | – | SF | HE, M48 (14.70) |
| M17; (TB); MP | 57.84 | 39500 | 0.6860 | 0.3028 | 0.028 | – | 0.0559 | 0.0535 | 0.0547 | 2.27 | 10.89 | 4.39 | FA | AP-T, T166E2 (1 |
| M8; (DB); Sheet (Four increments) | 1.87 | 4980 | 2.223 | – | 0.244 | 1.437 | Distance betw perforations 1.438 in; thickness of sheet 0.0080 in; Max variation in thickness 0.0014 in | | | | | | MA | HE, M56 (10.92 |
| M9; (DB); Discs in Ignition Ctges M3 & M6 | 0.274 | – | 0.0094 | 0.0589 to 0.0601 | – | – | – | – | – | – | – | – | MA | HE, M56 (10.92 |

**TABLE IX (cont)**

| Model, Type and Granulation of Propellant | Weight of Propellant Charge | Chamber Pressure, psi (Copper gage) | Grain Dimensions in inches L | D | d | W | $W_o$ | $W_f$ | $W_a$ | Ratio L/D | Ratio D/d | Difference: $\frac{(W_a - W_f) \times 100}{W_a}$ | Type of Ammunition | Type, Mode and Weight Projectile, I |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | In ounces | | | | | | | | | | | | | |
| M5; (DB); Discs (Eight increments) | 2.98 | – | 0.012 | 0.061 to 0.065 | – | – | – | – | – | – | – | – | MA | HE, M362 (9.42 |
| M9; (DB); Discs in Ignition Ctge M66 | 0.262 | – | 0.0114 | 0.0619 | – | – | – | – | – | – | – | – | MA | HE, M362 (9.42 |
| M6; (SB w DNT); (Sulf); MP | 116.73 | 36300 | 0.6452 | 0.2715 | 0.0240 | – | 0.0514 | 0.0486 | 0.0500 | 2.38 | 5.60 | 11.36 | FA | HE, M71 (23.40 |
| M17; (TB); MP | 141.58 | 44000 | 1.1437 | 0.4733 | 0.0533 | – | 0.0802 | 0.0765 | 0.0784 | 2.42 | 4.72 | 8.88 | FA | AP-T, M318A1 |
| M1; (SB w DNT); SP | 8.55(Z1)<br>9.98(Z2) | 6600<br>8200 | 0.249 | 0.0478 | 0.0192 | 0.0143 | – | – | – | 5.21 | 2.49 | – | SF | HE, M1 (33.00) |
| M1; (SB w DNT); MP | 12.51(Z3)<br>16.31(Z4)<br>22.08(Z5)<br>30.85(Z6)<br>45.25(Z7) | 9000<br>11000<br>14350<br>19800<br>31000 | 0.3541 | 0.1466 | 0.0140 | – | 0.0255 | 0.0269 | 0.0262 | 2.42 | 10.47 | –5.34 | | |
| M10; (SB); MP | 122.05 | 7100 | 0.4517 | 0.1944 | 0.0204 | – | 0.0330 | 0.0342 | 0.0336 | 2.32 | 9.53 | –3.57 | FA | HEP-T, M326 ( |
| M26; (DB); MP | 129.00 | 8600 | 0.5130 | 0.2217 | 0.0232 | – | 0.0373 | 0.0387 | 0.0380 | 2.32 | 9.56 | –3.68 | FA | HEAT, M344 (1 |
| M8; (DB); Sheet (Four increments) | 6.86 | 11500 | Sheet thickness 0.026 in; Length of sides 2.652 in; Width of sides 2.690 in; Average 2.671 in; Diameter of perforation 1.36 in | | | | | | | | | | MA | HE, M3A1 (25.1 |
| M9; (DB); Discs in Ignition Ctge M2 | 0.274 | No information at our disposal about dimensions of discs | | | | | | | | | | | MA | HE, M3A1 (25.1 |
| | In pounds | | | | | | | | | | | | | |
| M7; (TB); MP | 29.43 | 44800 | 1.545 | 0.642 | 0.063 | – | 0.118 | 0.110 | 0.114 | 2.41 | 10.19 | 7.02 | Sep A | AP-T (50.85) |
| M6; (SB w DNT);MP | 30.86 | 38600 | 0.6887 | 0.3067 | 0.0287 | – | 0.0556 | 0.0547 | 0.0552 | 2.25 | 10.69 | 1.63 | SLA | HE, M101 (95) |

## TABLE IX (cont)

| Model, Type and Granulation of Propellant | Weight of Propellant Charge | Chamber Pressure, psi (Copper gage) | Grain Dimensions in inches L | D | d | W | $W_o$ | $W_i$ | $W_a$ | Ratio L/D | Ratio D/d | Difference: $\frac{(W_o - W_i) \times 100}{W_o}$ | Type of Ammunition | Type, Mod and Weight Projectile, |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | In pounds | | | | | | | | | | | | | |
| M1; (SB w DNT, Sulf); MP | 4.15(Z3)<br>5.32(Z4)<br>7.05(Z5)<br>9.82(Z6)<br>13.20(Z7) | 5500<br>7000<br>10250<br>17500<br>31000 | 0.4033 | 0.1763 | 0.0143 | – | 0.0332 | 0.0336 | 0.0334 | 2.29 | 12.33 | -1.20 | SLA | HE, M107 (95) |
| M6; (SB w DNT); MP | 20.58(Z1)<br>37.75(Z2)<br>55.56(Z3) | 11500<br>17600<br>43600 | 0.9614 | 0.4187 | 0.0425 | – | 0.0736 | 0.0720 | 0.0728 | 2.30 | 9.84 | 2.20 | SLA | HE, M437 (147 |
| M6; (SB w DNT); MP | 80.89(red)<br>92.27(nor) | 29300<br>37600 | 1.1520 | 0.4815 | 0.0487 | – | 0.0851 | 0.0826 | 0.0839 | 2.39 | 9.89 | 2.98 | SLA | HE, M103 (240) |
| M1; (SB w DNT); MP | 16.62(Z5)<br>21.84(Z6)<br>28.05(Z7) | 12900<br>19800<br>32000 | 0.5574 | 0.2403 | 0.0249 | – | 0.0425 | 0.0402 | 0.0414 | 2.32 | 9.65 | 5.56 | SLA | HE, M106 (200) |
| M6; (SB w DNT); MP | 43.64(Z1)<br>54.01(Z2)<br>66.59(Z3)<br>79.75(Z4) | 10400<br>15100<br>22900<br>34000 | 0.9550 | 0.4154 | 0.0426 | – | 0.0726 | 0.0711 | 0.0791 | 2.30 | 9.77 | 2.08 | SLA | HE, M114 (360) |
| M6; (SB w DNT); MP | 106.4(red)<br>140.0(nor) | 19000<br>31700 | 1.3093 | 0.5336 | 0.0505 | – | 0.1023 | 0.0888 | 0.0956 | 2.45 | 10.57 | 14.12 | SLA | HE, M350 (800) |

**Abbreviations Used in Table IX:** **ammo** – ammunition; **AP** – Armor-piercing; **AP-I** – Armor-piercing-incendiary; **AP-T** – Armor-piercing-tracer; **Cal** – Caliber; **Ctge** – Cartridge; **D** – of grain perforations; **(DB)** – Double-base propint; **FA** – Fixed ammo; **fps** – Feet per second (0.3048 m/sec); **HE** – High-explosive; **HEAT** – High-explosive-antitank; **HEP-T** – Hig Howitzer; **in** – inch (25.4mm); **L** – Length of propint grain; **M** – Model or Modification; **m** – meter (3.2808 feet); **MA** – Mortar ammo; **MP** – Multiperforated (7) grain; **nor** – normal; **psi** – pounds per square inch (0.07031 kg/sq cm); **Rec R** – Recoilless rifle; **red** – reduced; **SA** – Small arms; **SB** – Single-base propint; **Sep A** – Separated ammo; **SFA** – Semi-fixed a **SP** – Single-perforated grain; **Sulf** – Sulfated; **T** – Experimental M; **(TB)** – Triple-base propint; **W** – Web thickness of SP propint grain; **w** – with; $W_a$ – Average web of MP propint gr $W_o$ – Outer web of MP propint grain; **Z** – Zone

*Note:* Compositions of M1, M2, M5, M6, M8, M9, M10, M17 & M26 are given in Tables V, VI, & VII, under CANNON PROPELLANT

# SUPPLEMENT TO THE LIST OF THE BOOKS ON EXPLOSIVES AND RELATED ITEMS GIVEN IN VOL 1, p A676

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A cumulative alphabetical listing of items discussed in Vols 1 & 2, which may not necessarily begin with letters A, B & C, but which may represent alternate names of items or compounds already listed alphabetically in the text. *NOTE:* All page numbers preceded by alphabet letter A refer to Vol 1; pages preceded by letters B & C are found in Vol 2.

## A


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